THE WORKS OF CHARLES CAMMELL & COMPANY, LIMITED, SHEFFIELD.

AMONG the great iron and steel producing establishments of England, the colossal works of Messrs. Charles Cammell & Company, Limited, of Sheffield, are to be classed in the very foremost rank.

On steel being exclusively adopted for the production of heavy ordnance, Messrs. Cammell successfully entered into the business, and in consequence of an increased call for this work and heavy marine forgings, large forged cylinders, etc., a very powerful forging press was erected at the Grimesthorpe Works. This is one of the most powerful machines of its kind in existence. Attached to this press are two very powerful traveling cranes with a lifting power of 150 tons each. It was also found necessary to erect larger open

hearth melting furnaces here, some of which take a charge of forty tons. These works are thus enabled to produce steel forgings or castings of any weight and size up to 120 tons.

Quite recent experiments having proved the greater resistance of mild homogeneous steel "Harveyed" armor plates over other systems of production, Messrs. Cammell were again foremost in the field, and have erected plant and machinery for the manufacture of this class of armor which are assuredly second to none.

In a recent test the trial plate withstood the impact of five "Holtzer" forged steel shot fired at the extreme velocity, all of which have splashed against the face with little or no penetration, and not the slightest sign of even a hair crack.

Throughout all their works the company employ about 10,000 men.

The press shop is an exceptionally fine building and is known in the works as the "cathedral." The press

is worked by hydraulic pressure of 2½ tons to the square inch, and has two rams. It is truly a ponderous piece of mechanism. This, with its complement of reheating furnaces and cranes, are all the shop contains. The engines to supply the power (the cranes and manipulating gear are worked from another source) are in an adjoining building. They have a pair of horizontal cylinders 36 inches in diameter and 5 foot stroke, the steam pressure being 70 pounds.

The pumps are worked direct from the crank shaft by return rods, and there is no accumulator.—*Engineering Review.*

SINKING SHAFTS BY THE FREEZING PROCESS.

THE Mining Company of Anzin, in France, in the

boring at Vicq, a place southeast of Thiers, found at a depth of about 10 feet below the surface a quicksand about 20 feet deep. A few feet lower down through a bed of argillaceous sand of Tertiary age, they found a deposit of chalk of Cretaceous age full of fissures and cracks, and shedding a large volume of water at such a high pressure, that it came gushing out at the surface; the line of the bore hole having cut into the center of the chalk measure basin, that is overlaid with compact impermeable Tertiary rocks. The cracks and water shedding continued down to a depth of 42 fathoms, or 252 feet, when a bed of bonne pierre (meaning good stone) was reached. This bed was a compact limestone suitable for building purposes, and after passing through a bed of chalk (with flints) 41 feet thick, and at a total depth of 55 fathoms, the rock called the bleus was reached. This rock is a strong, impermeable stratum 36½ feet thick. As the water-bearing measures at Vicq have a depth or thickness of 110 yards, the freezing process was the only one

that offered any hope of success, and it was, therefore, adopted.

Briefly let us notice that the Poetsch freezing process was invented to soldify a quicksand, so as to provide an ice dam to keep back the sand and water, until the sinking had progressed through it, and a permanent dam had been fixed within the ice one.

But in this case the conditions that give preference to the Kind Chaudron process of boring a shaft through water-bearing rocks would not apply to a quicksand. It was therefore imperative that not only the Tertiary quicksand, but the secondary chalk should be frozen to restrain the outrush of its high-pressed water. This the latest triumph of the Poetsch process is a marvel not only in mine engineering, but in the application of science to art, for it attempted nothing less than freezing a saturated rock mass or a

gigantic rock cylinder about 21 feet in diameter and 330 feet long. Before the surface of the sites of the shafts was broken, it was designed to sink two large round shafts 40 yards apart, one to be finished as the winding shaft 16 feet 5 inches in diameter and the other 12 feet in diameter.

To safely inclose, however, the section of shaft, as cut in the rock, the diameter of the cylinder of frozen rock was fixed at 21 feet for the large shaft and 17 feet 3 inches for the small one.

It will be seen that the rock required to be frozen before the sinking was commenced, and for the insertion of the freezing tubes, holes had to be provided, and they were made 6 inches in diameter and 330 feet deep in passing through the chalk, but the holes had to be made larger down to the bonne pierre to obtain a watertight joint in that rock, for the piezometric level of the water in the chalk is above the surface level of the holes, and they had therefore to be lined with sheet iron tubes 10·25 inches in diameter, which

THE PRESS SHOP OR "CATHEDRAL," AT THE WORKS OF MESSRS. C. CAMMELL & CO.

were made watertight to the chalk water, so as to prevent it escaping up the hole outside of the tubes, and this was done by drilling the hole into the bonne pierre, and setting the bottoms of the tubes into a foundation of cement.

The upper ends of the lining tubes were carried above the piezometric level, to prevent an outflow from the chalk during the freezing, for unless the chalk water was at rest in situ, it could not be frozen.

To freeze this cylinder of rock for the large shaft, the bore holes were cut around a circle 22 feet in diameter, and there were 30 holes in the circle, all a meter, or 39½ inches apart.

For the small shaft there were 16 holes in the circumference of the circle 17 feet in diameter.

After the holes were drilled the circulating pipes were fixed, the outside tubes were 5 inches in diameter and the inside ones were 1⅞ inches in diameter. The circulation of the cold fluid is a pretty illustration of the multiple splitting of fluid currents. All the small pipes were branches from a ring pipe that distributed the cold fluid into them, and the large or outside tubes were connected to a ring pipe that collected the returning fluid and passed it on to the refrigerator. The small tubes entered the large ones through a water-tight cap. The result was the cold fluid passed down the inside small tubes, and returned up through the annular space between the small and large tubes, doing the work of chilling and freezing until it collected in the top ring. Thus in each hole there was a double column of tubes, one within the other.

The freezing was effected in six months, when the miners began to sink within the ice cylinder; the average daily advance with the sinking was 13 feet. The medium for the transmission of cold was a saturated solution of chloride of calcium. The refrigerator was the Linde machine. The total length of piping required for the circulation of water, steam, chloride of calcium, and ammonia was about ten miles, and the example before us is the grandest of its kind known in the modern achievements of mine engineering.—Colliery Engineer.

HALF A CENTURY OF CYCLES.

"WHOEVER invented the bicycle," says Lord Charles Beresford, "deserves the thanks of humanity." And this brings us to the question, "Who did invent the bicycle?" It must be conceded at once that to no one individual can we award the palm of merit, or pay the debt of gratitude Lord Charles Beresford enjoins upon us. The bicycle, as it stands to-day, has passed through a period of evolutions of the most variform kind, a long series of invention after invention combining to make one of the most interesting records in the realm of mechanical science.

The dandy, or hobby, horse is of course associated in the minds of most people with the mention of the origin of the bicycle, but the best that can be said for this cumbrous vehicle is that it contained the germ of the idea which was destined to be so fully developed—namely, that the rider should be seated while traveling by his own efforts on a single track. Steering and balancing were still unthought of.

The original hobby horse is believed to have appeared in Paris in 1808, and the connecting bar between the wheels was carved to represent in some degree a horse. But in 1818 an improved pattern was patented in France by a German, the Baron Von Drais, of Saverbrun, near Frankfort. A London coach-maker—Dennis Johnson by name—soon afterward constructed a similar machine, which he dubbed "the pedestrian's curricle, or dandy horse." For a time it was all the rage, and Mr. Johnson did a brisk business, but the caricaturists and its own inherent defects combined to kill this form of curricle. Among those who had ridden it, and "lived to tell the tale," was Mr. Robert Lowe, who thus early manifested a taste for which, long years afterward, as Lord Sherbrooke, he was so well known. The dandy horse was revived abroad and improved in 1830 by M. Dreuze, of the French post office, for the benefit of the rural postmen; but, after a time, even they were forced to discontinue its use. Until quite recently it was supposed that nothing more was done in the way of two-wheeled appliances for many years, though all manner of clumsy "velocipedes," "accelerators," "manivelociters," and the like, having three or four wheels, were from time to time invented.

THE FIRST CRANK-DRIVEN BICYCLE.

But within the last five years two discoveries have been made. An old wooden and iron machine was exhibited at the Stanley show of 1889, which differed from the hobby horse in the all important particular that it had cranks and pedals—though of a very primitive kind—and was, therefore, a practical bicycle, in that it was not propelled by alternately striking the road with the toes, but by continuous pedaling, involving the art of balancing and the keeping of "an even keel." This machine was the product of one Gavin Dalzell, a cooper, of Lesmahagow, Lanarkshire, and it was supposed to have been made some fifty years previously. For two years or more Dalzell was posthumously glorified as the inventor of crank driving, and therefore of the bicycle as now understood.

But in 1892 a more pertinacious scrutiny into the matter disclosed the fact that Dalzell's bicycle was built in 1846, a blacksmith's bill for the iron work being unearthed, while the further fact was ascertained that several years previously, Kirkpatrick Macmillan, a clever mechanic, of Courthill, Dumfriesshire, had invented a machine of which Dalzell's was but an imitation. To Macmillan, therefore, is due all the credit which attaches to the application of crank driving. It should be explained, however, that even in his case the crank action was not rotary, the feet simply describing a small segment of a circle, in a downward and forward thrust, with return. Macmillan, who was a powerfully built man, put his bicycle into practical use, and regularly journeyed between his home and Glasgow, a distance of fourteen miles. At first the innovation was so provocative of wonderment that Macmillan was actually locked up in Glasgow for causing a crowd to collect and creating an obstruction. There is no evidence to show, however, that Macmillan's invention was known south of the Tweed, and some credit must, therefore, be given to Messrs. Mehew, of

Chelsea, who, at the exhibition of 1862, showed a three wheeled velocipede, to the front wheel of which crank action was applied. This is the only claim, however, which English inventiveness can make in regard to the birth of the bicycle.

THE "BONESHAKER" AND ITS SUCCESSORS.

A year or two later Pierre Lallement, a mechanic in the employ of Messrs. Michaux & Company, of Paris, produced a machine of two wheels, with cranks to the front wheel, after the manner of the Chelsea velocipede. Thus was born the famous "boneshaker." The French people, by the way, erected a memorial last year to M. Michaux, as "the inventor of the bicycle;" though why Lallement should be deprived of glory in the matter is by no means clear. In January, 1869, a Mr. Turner, Paris agent for a Coventry firm of sewing machine makers, brought one of the new machines to London, and thence to Coventry. The sewing machine trade, as well as the ribbon trade, was just then failing, and the prosperity of Coventry was fast declining, but the cycle appeared to offer a new outlet for ingenuity and enterprise. The Coventry Machinists Company accepted an order for a hun-

THE FIRST CRANK-DRIVEN BICYCLE.

dred machines, and inventors, including the late James Starley, than whom no one did more toward perfecting the bicycle, turned their best energies in this new direction.

To follow the bicycle through all the phases of its evolution from that time till now would involve the description of innumerable technicalities.

Some brief mention of the main types, however, is necessary. The boneshaker was succeeded by Starley's "Ariel," and then the "Spider," in each of which the front wheel was enlarged and the rear wheel reduced—in the second case so much that it was almost identical with the "ordinary" or high bicycle. Wood rims and spokes gave way to the suspension wheel, with anti-friction bearings and rubber tires, and for years the "ordinary" was in general use, varying only in size at the option of the rider and in very minor details. Length of limb now became the desideratum of every cyclist, for, other things being equal, the longer the leg, the larger the wheel that could be ridden, and therefore the greater the stretch of ground covered at each revolution of the pedals. But undeniable dangers attached to the use of the ordinary. So easily was the equilibrium of the rider disturbed that a pebble in his path would cause him to pitch head foremost over his handle bars, describing a parabola of greater or less arc, according to the rate of his progression. "Coasting" down hill, "legs over handles," was a favorite diversion, the rider being occasionally found senseless on the highway as a result. Endeavors to devise machines of safer form resulted in the appearance of the "Facile," the "Xtraordinary," the "Pony" and the "Kangaroo" types. All these, however, were front drivers. Experiments in the way of utilizing the back wheel, except as a trailer, had not been tried since Macmillan's day.

Toward the end of 1879, however, Lawson's "Safety" saw the light, and though he himself did not persevere with his invention, it was the virtual parent of the rear-driven safety now ridden everywhere—albeit it


THE "BONESHAKER" OF THE MIDDLE AGES.

was very different in appearance, and the cranks were actuated by levers and not a chain, but it led the way to the appearance of Starley's famous "Rover."

Though at a casual glance the modern "safety" is unrecognizable in this machine, it embodied the vital points of the former. The wheels were low, and of nearly equal size, and the long chain was used for the first time. It is true that the "Kangaroo" bicycle had twin chain couplings, but these were short, and applied to the front wheel. In many structural particulars the safety of to-day differs considerably from the "Rover," but the driving principle is the same, and to all appearances destined to remain so. The most recent forms of geared front drivers, such as the "Crypto" and "Bantam," have had a certain share of popularity even since the perfection of the rear driver, but in point of numbers the last named has an overwhelming superiority.

THE TRICYCLE.

The part played by the tricycle in the history of

cycle construction is too important to be altogether ignored. Tricycles and quadricycles were in existence before even the hobby horse was heard of. Horrible instruments of torture they must have been, however, to the riders. Some were designed to carry several passengers, a wretched footman at the back supplying the motive power. In a crude fashion these embodied the principle of the modern coolie cycles of which Eastern potentates appear so fond. Like the two wheeler, the tricycle has had its period of front driving and rear driving, and has passsed through many evolutionary phases. Loftiness of wheel, as in the old "Humber," has gradually given place to the lowly 30 inch or less, and the tricycle of to-day is simply a three-wheeled safety. The chain drives two wheels instead of one, and these two wheels must of necessity be bridged. In all other respects—bearings, fittings,
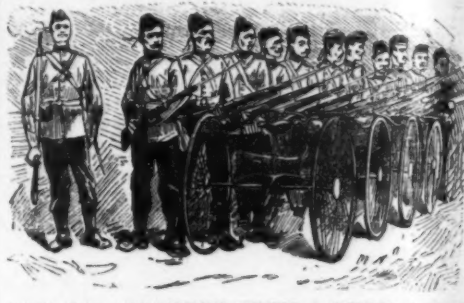
CYCLIST INFANTRY WITH A MULTICYCLE.

construction of the wheels, handle bars, etc.—the two machines are identical. The one great service which the tricycle has rendered to the science of cycle building is the fact that the value of the chain was established by trial in various forms on the three wheeler, and thus led to the inception of the "Rover" safety.

THE MODERN MACHINE.

An impressionable Italian has defined the bicycle as "a poem in metal." The definition is defensible. A poem is a work of art; so is the cycle of to-day. There is not a single angle in its design, nor one fractional part of its mechanism, that is not the outcome of the most careful thought and long experimenting. In no other department of mechanical construction has the desideratum of "lightness with strength" so conspicuously been attained. Light as is the modern cycle, it requires much pushing over rising ground, and even with a machine of the "featherweight" description one is forced occasionally to pant and sigh for a pound or two less of metal. On the other hand, when flying a steep hill—if it be a safe one as regards absence of turns and traffic—at a rate verging on thirty miles an hour, one is made to feel how tremendous is the strain thrown upon that apparently insubstantial piece of mechanism beneath you, and how necessary it is that all the working parts should be of the highest grade of workmanship, and absolutely without flaw.

CYCLE BUILDING A SCIENCE.

But to such a pitch of perfection has the science of cycle building attained that, notwithstanding the added weight of the pneumatic tires as compared with the old "solids," a machine fit for general road work can now be turned out at a weight of 30 pounds, including brake and steel mud guards—accessories

THE "DANDY" OF PREHISTORIC TIMES.

with which some riders dispense, and thereby reduce the weight by three or four pounds. The machinery employed in producing a bicycle so light and yet reliable is both elaborate and costly, and extraordinary care is taken in the application of tests. The tubing which forms the main framework of the machine is subjected to the most rigorous trials to ascertain whether it will withstand the many strains—twisting, breaking, doubling, and the like—to which it is liable in actual use. But when we come to the finer parts of the modern cycle, a description of the processes by which they are produced would be of too technical a character for an article written in the interest of the general reader. The part played by "ball bearings," however, which have so effectually superseded the "parallel," "cone" and "roller" bearings of the old "ordinary" days, is so important that one reference thereto must be made. They have reduced friction apparently to the irreducible minimum. So great is the nicety of their manufacture that the best micrometer gages are ineffectual for the purpose of testing

their accuracy, and "gage plates" of hard cast steel have to be used instead. Each plate is provided with six holes, the largest of which is only about one-thousandth of an inch larger than the smallest. Consequently there is but one six-thousandth of an inch difference in size between the ball which will just pass through the second hole and that which will just pass through the first. When such accuracy as this is brought to bear on the construction of a cycle, one can understand how it is that the front wheel of a "safety" has been known to continue in motion, after a single

THE TRICYCLE OF 1895.

downward pull, for no fewer than thirty-eight minutes!

A WHOLESOME INFLUENCE.

And let it not be imagined that the ingenuity of cycle builders has had no effect on other departments of engineering science than their own. In a recent number of the Engineer appreciative reference is made to

"   . . . a branch of mechanical engineering which has already has its influence in other branches of mechanical work, and will probably in the near future have greater influence on the construction of various kinds of road vehicles. It is not many years since mechanical engineers looked upon roller bearings and ball bearings as devices not consistent either with good

THE FIRST "ROVER."

or permanent work, or as likely to lessen the frictional resistance of machinery fitted with them. We owe it to cycle manufacturers that they have proved that for many kinds of machinery ball bearings not only provide a permanent and satisfactory means of carrying rotating pieces, but that they afford a most simple means of adjustment, and at the same time reduce the journal friction of such machines by from 30 to 60 per cent. It must be admitted, also, that we owe it to cycle manufacturers that it has become possible to construct road vehicles which are lighter in weight and draught, and more comfortable for the riders, than

could have been the case without their experience, not only in the use of light steel tubes, of light suspension wheels, in the development of India rubber-tired wheels, but in the proof of the superiority of spring wheels."

POINTS OF IMPROVEMENT.

In briefly reviewing the points of improvement in the 1895 pattern of safety as compared with its progenitor, the "Rover," it must be obvious to the most casual glance that the strain-resisting qualities of a machine are now greatly increased. In the first

LATEST TYPE OF "SAFETY."

"Rover" the weight of the body was supported on a slender, unsupported framework only, whereas the whole aim nowadays is to meet every direct strain in a direct manner. Hence the substantial back tube leading straight from the saddle pillar to the chain wheel bracket. This principle is now so completely followed out that even the saddle pillar is made in the shape of the letter "T," with the primary object of placing the saddle directly over the tube instead of on the arm of what is known as an "L" pin. The handle bars have undergone many changes, the prevailing 1895 pattern being undoubtedly the most satisfactory. In this the handles are "undropped," and facilitate the keeping of an upright position instead of the much decried "bicyclist's stoop," which the public should remember
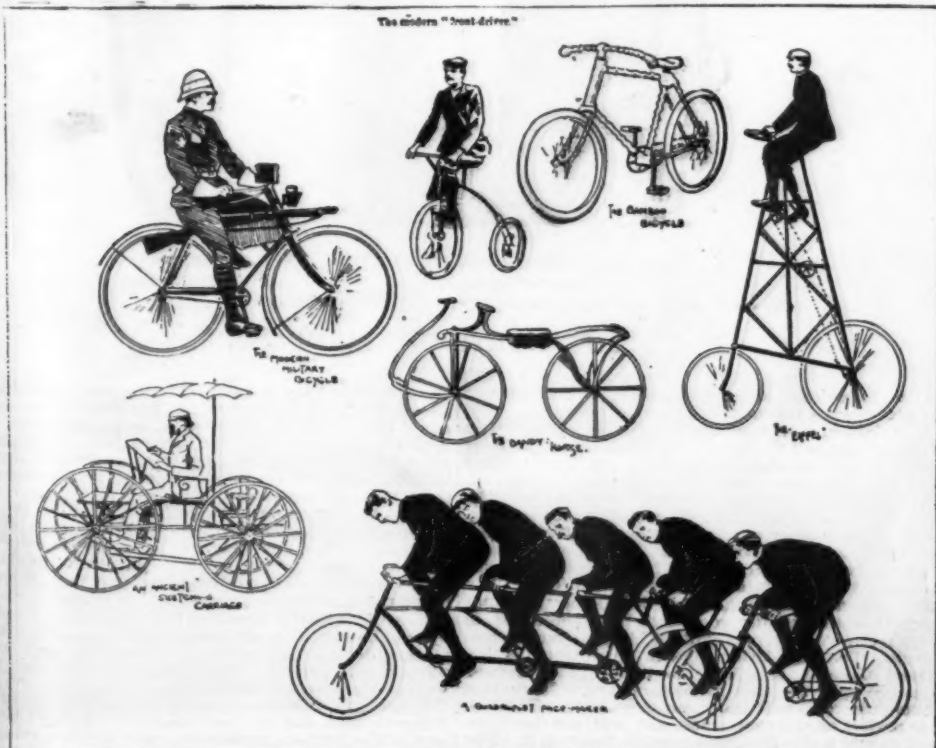

THE NEW BICYCLE.

is by no means a necessary consequence of cycling, but is simply a matter of how the rider chooses to have his handles fixed. Another important point to be noted is that the handle bars are now much narrowed in radius, bringing the arms into a more natural and easy position than heretofore. In general appearance the machines of to-day seem to be heavier than formerly. As a matter of fact they are lighter, but are built with tubing of greater diameter, though of thinner gage. The combination is believed to effect a gain in strength, while also reducing the weight. In many minor points, too technical to enumerate, the

original "Rover" has been improved upon; but a word should be said with respect to the process of brazing, or welding the parts of the frame into each other by the application of heat. The extent to which this has been improved is shown by the building of a machine such as the "Eiffel" of Messrs. Humber & Company, a mere glance at the numerous light joints of which will show how important the brazing process is. This machine is 13 feet 6 inches high, and at the "Anchor Shield" procession, on March 28 last, was an object of universal attention as it glided along in face of a strong wind. Another example of cycle building is the quadruplet, for four riders. These machines are occasionally used for "pacing" purposes on the track, for the assistance of "record" breakers. The bamboo cycle is interesting as a modern product, and has excited some attention, but for the determination of its precise value a little more time is needed.

THE PNEUMATIC TIRE.

But great as have been the improvements in mechanical construction which have contributed to the various astonishing feats on race path or road, it is to the supplementary aid of the air tire that these performances are principally due. The story of the pneumatic tire is one of the romances of trade; seldom has a simple invention had so startling or revolutionary a result. A Belfast surgeon, Mr. John Boyd Dunlop, though not himself a cyclist, was desirous of discovering, for the benefit of his cycling sons, some means of preventing the vibration of which they complained when riding solid-tired machines over rough roads or granite bowlders.

After much experimenting he was able to construct a tire which would hold air, though further difficulties had to be solved in the way of suitable valves and rims. When, in 1888, the first air-tired machines appeared on the race path in Ireland, and afterward in England, they were a source of amused astonishment, but their riders, nevertheless, "swept the board." It was but a question of time to establish the absolute superiority of the new invention, and Englishmen who have so largely gained thereby in comfort should not forget the debt they owe to Ireland in this matter. Despite the fact, however, that the English championships were secured in 1890 by Irishmen on the pneumatic tire, there was still a natural reluctance on the part of English manufacturers to welcome the new comer. They had thousands of solid tired machines in stock, and there was a justifiable fear that the air tire might not stand the wear and tear of all-round riding.

It was discovered to have several failings, being liable to slip, to burst, and to be punctured. When punctured, moreover, it was most difficult to repair, as the original variety was cemented fast to the rim, and could only be detached by the application of heat. All this is changed to a remarkable degree. In 1892 the company which had been formed in 1889 to manufacture the Dunlop tire produced a new pattern, the invention of Mr. C. K. Welch, which was wired on to the rim and easily detachable. All that was required in case of puncture was to deflate the tire of its air, raise the edge of the outer cover, or, if necessary, remove it altogether, and affix a small patch of India rubber on the air tube wherever the puncture might be.

Not only is the repair of a puncture, therefore, now a comparatively trifling matter, but the necessity for it is a matter of infinitely less probability than formerly, owing to the outer cover having been improved. While it is true that a stray piece of glass or thorn may attach itself to a tire when the rider has barely left his doorstep, and gradually force its way into the air tube, instances have not been wanting of men who have ridden ten thousand miles without accident. One puncture in three thousand miles may be set down as the average of probability with roadster tires, though many a man goes right through the season without trouble. Road racers who use path racing tires on the highways court catastrophe, and are of course less fortunate. Bursting is now practically unknown. It certainly never enters into the ordinary rider's calculations, though if he leaves his machine standing in an unusually hot sun, with the tire pumped very hard, it may perhaps go "pop!" The "side slip bogy," by which is meant the tendency of the broad-based, smooth-faced air tire to "skid" on greasy roads, is unfortunately still with us; but various appliances have considerably mitigated the evil. Whatever drawbacks the pneumatic tire may still possess are amply compensated for by its qualities of increased comfort and speed. The solid tire is dead, and the cushion moribund; considerations of the pocket alone keep the latter alive. That the superiority of the pneumatic is absolute has long since ceased to be matter for argument. It is a case of "once used, always used."

A HAND AND FOOT CYCLE.

A little group of members of Parliament recently gathered on the Victoria Embankment, near Westminster Bridge, for the purpose of witnessing the first trial in England of a new bicycle to be propelled by hands and feet. The invention is French, and was shown at the recent Cycle Exhibition in Paris, where it attracted a good deal of attention; but it is only within the past few weeks that it has been applied to any English machines. It consists of a pair of levers connecting the handles with the chain wheel, and so arranged that when the handles are alternately pressed down considerable force is brought to bear upon that wheel, the right hand and left foot acting simultaneously, and vice versa. It is claimed for the new machine that it exercises all the muscles of the body—the arms as well as the legs—and that it adds at least 20 per cent. to the power exerted, thus allowing a much higher gearing to be used, and a largely increased speed to be attained. The steering, it is said, can be thoroughly mastered by a bicycle rider after a very few days' practice, as the learner can in a moment when he experiences any difficulty shift his hands to the rigid handle bar and ride the machine with feet alone in the ordinary way. The bicycle shown on the Embankment is to be known as "the New Howe of Glasgow Flying Machine," but the patent can be applied to almost any safety bicycle.

Judging from the trial on the Embankment, the new invention appears a very great advance on anything in the way of a hand and foot machine which has yet been seen in this country, though whether it will, as

THE HISTORY OF CYCLING—SOME PAST AND PRESENT MACHINES.

its promoters expect, revolutionize the sport of cycling remains to be seen. The rider had only mounted it on three previous occasions, but he nevertheless seemed to experience very little difficulty in steering it, and he propelled it at a high rate of speed with apparently little exertion. A prominent Ulster Unionist member of Parliament, who is a bicyclist, afterward volunteered to test the invention; and although he dismounted somewhat suddenly soon after starting, he quickly mastered the difficulties of steering, and was soon careering gayly up and down the Embankment with only occasional recourse to the handle bar. The "flying machine" should certainly have a future before it in mountainous districts, as the invention would seem to be peculiarly well adapted to hill climbing.— The London Daily Graphic.

[FROM THE INDUSTRIAL RECORD.]

THE NORTHROP LOOM.

IN response to an invitation from George Draper & Sons, Hopedale, Mass., a representative of the Industrial Record visited this firm's works quite recently for the purpose of examining the latest and most important mechanical innovation in the art of weaving that has been placed upon the market within the last fifty years, and within its special province the most important, and, in a sense, the most wonderful advancement that has been made in automatic weaving within the last century. Its conception and development has required the highest order of inventive genius, and the revolution it seems destined to bring about is incalculable. A new era in weaving has apparently been established, quite as marked in this particular line as the introduction of the self-acting mule was to spinning.

The principal features of this special mechanism of the loom are the shuttle, the transferrer or pusher, the hopper and the filling fork. All of these we illustrate herewith, excepting the filling fork, which cannot be very well shown, but which every weaver will understand what is meant, only it should be understood that its functions are not those of stopping the loom when the weft fails in the shed, but are to determine the time at which the pusher shall act to put a bobbin into the shuttle. These devices can be attached to any plain cotton loom with very few alterations, to allow the attachment to the end of the lay of the parts containing the hopper, and certain changes in the filling fork connections. Though at present the invention is confined to the plain cotton loom, in which the single box alone is used, the probabilities are that it will, in time, be developed to permit of its becoming operative upon more complicated looms, even those carrying drop boxes. The genius that has carried it thus far from the realm of seeming impossibilities is not to be restricted to the limitations of the ordinary artisan.

In speaking of these devices, the principal credit is due to their chief inventor, James H. Northrop, whose name has already been enrolled among those of the greatest inventors of the age. The purpose of the invention is that, when the filling breaks or becomes exhausted from the shuttle, other filling will be automatically supplied thereto without any intermission or stopping of the loom, the construction of the parts being such that the introduction of the filling may be effected even while the loom is running at a high speed. The bobbins of filling are held in a circular hopper, the rotation of the hopper delivering each in turn into proper position. The lay on each alternate forward stroke brings the shuttle directly under the hopper, where a simple movement of the transferrer or pusher effects the desired operation when necessary. This transferrer is pivoted, and receives its rotating movement, when in operation, by a direct blow from a bunter on the lay. The motion is therefore positive, not depending on a spring or weight. The operative places the bobbins in the hopper by hand, winding the end of filling around a stud. The hopper holds fourteen bobbins, or more if necessary, and it takes about one minute and a half to fill it. Compare this with the time taken with the old method to go to a loom, take out the shuttle, put in the new shuttle, place the lay, start the loom, take off the empty bobbin, put on a full one, suck the thread through the eye and put the shuttle in the holder, and all this to be done fourteen times for comparison, and we have one hundred and twelve operations against twenty-eight, irrespective of the fourteen journeys. Bobbins that are partly woven off can be put in the hopper as well as full ones, and there will be less waste with the hopper loom, as the operative will find it easier to put a small bobbin in the hopper than to rub or cut off the filling. Co-operating with the filling fork is a cam slide so arranged that, should the shuttle fail to thread twice in succession, the loom will stop. This is to prevent weaving a thin place in case the hopper is exhausted, or anything out of order which prevents proper action. A device called a position detector is attached to the rod worked by the fork slide, and when the bobbin is to be changed, a finger set in proper relative position reaches forward across the lay. Should the shuttle have rebounded excessively or not reached "home" properly, this finger will touch it, and when so stopped prevents the transfer of a bobbin. Should this occur twice, the loom will stop and give evidence thereby that the fixer should set the pick properly.

In order that the ejected bobbin should go into the box properly, a guide working with the transferrer swings toward the lay at the proper time and forms an incline down which the spent bobbin slides to place.

As regards the use of cops in these looms, it has been found to be perfectly feasible. Metal skewers having a base like a bobbin are used, and these are placed in the usual hoppers. Experience with cops, however, is as yet rather limited as compared with the use of bobbin filling, but orders are being taken for cop looms, and the Messrs. Draper have no question but that they will give every possible satisfaction. On the plain loom for new mills there is no need of raising the point, as such mills on ordinary numbers are universally using bobbin filling.

We desire to call attention to the illustration of the head of the bobbin, which is the only part of the latter essentially differing from the ordinary. It will be observed that the head is provided with two annular rings, which fit with great exactness into correspond-

ing recesses in the shuttle, which can be seen in the perspective view. These are intended to hold the bobbin firmly in position in the shuttle and to allow its being readily rolled or pressed into and discharged from the latter. Owing to the rapid movement of the lay and the brief space of time that the shuttle rests in the box after being thrown by the picker stick, the difficulty of inserting filling into the shuttle becomes apparent. To overcome any difficulty of this kind the inventor has considered three important conditions, first, by making the bobbin cylindrical, so that it may roll into place; second, by inserting the bobbin while the lay is moving forward, which motion materially aids in the rotation of the bobbin in a proper direction to enter the shuttle; third, by inserting the bobbin while the lay is at the slowest period of its movement.

The self-threading device of the shuttle is seen in the illustration. This is an important feature of the invention, so that when the bobbin is inserted automatically into the shuttle from the hopper, the filling thread will be automatically laid into the delivery eye of the shuttle for proper weaving. The shuttle, as will be seen, has an open bottom as well as top, and holds the bobbin by means of spring jaws acting on large metal rings attached to the bobbin base. When a new bobbin is put in it crowds the spent one out, the latter falling through the bottom of the shuttle onto a guide which delivers it into a box. The shuttle has an incline, and several notches in the springs, so arranged as to permit a bobbin to be put in when the shuttle may be in various positions, according to the wear of the picker or its rebound, etc.

It is claimed that the new loom will accomplish a saving of one-half the labor cost of weaving; make far better goods; produce more cloth per loom; easier work for operatives; less fixing and less stopping.

The Hopedale Machine Company, in going into the loom business, has determined to make as good a reputation as their other products have established. Expense has not been considered. For example, their loom has two hundred pounds of extra cast iron put in where it will add to strength and steadiness. The frame is iron throughout, and in details they have not been content to blindly copy, but have improved in every point where expert skill could point out former defects. The main driving gears have teeth of improved shape, far less liable to break. The harness cams are split for ease in replacement. There is a locking clamp to hold the beam in position. The fork is as perfect as any ever made, and will not be damaged should a shuttle smash occur in front of it. The beam heads are turned smooth on the face. The check is the very best. Eighty of these looms have been run continuously for more than a year as a test, and every
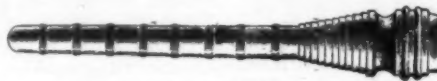
possible improvement that could be suggested by that test has been incorporated in the present manufacture. A complete plant of modern tools has been bought, and large additions have been made to the works.

George Draper & Sons have introduced machinery in the past that in its sphere of use has saved over 100,000 horse power per annum, has doubled the efficiency of more than 20,000 operatives, and nearly doubled the production per spindle of every mill in the country. Never before, however, have they attempted the solution of so important a problem as this one, involving a possible reduction of expense amounting to one-quarter the entire labor cost in a mill and raising the quality of the cloth to a grade never before possible.

The weakness in the present system of weaving lies in the extreme labor cost required in the weave room. There are so many hand operations necessary that the scope of the weaver is very narrow.

As finally developed this improved loom carries a supply of fourteen bobbins of filling in a hopper, which number could easily be increased. The weaver is, therefore, relieved of thirteen or more journeys to the loom that would have formerly been necessary. A very important point also from a humanitarian standpoint is the fact that this loom relieves the weaver from the unhealthy act of sucking the filling through the eye of the shuttle, and injuring the lungs through the cotton fiber inhaled.
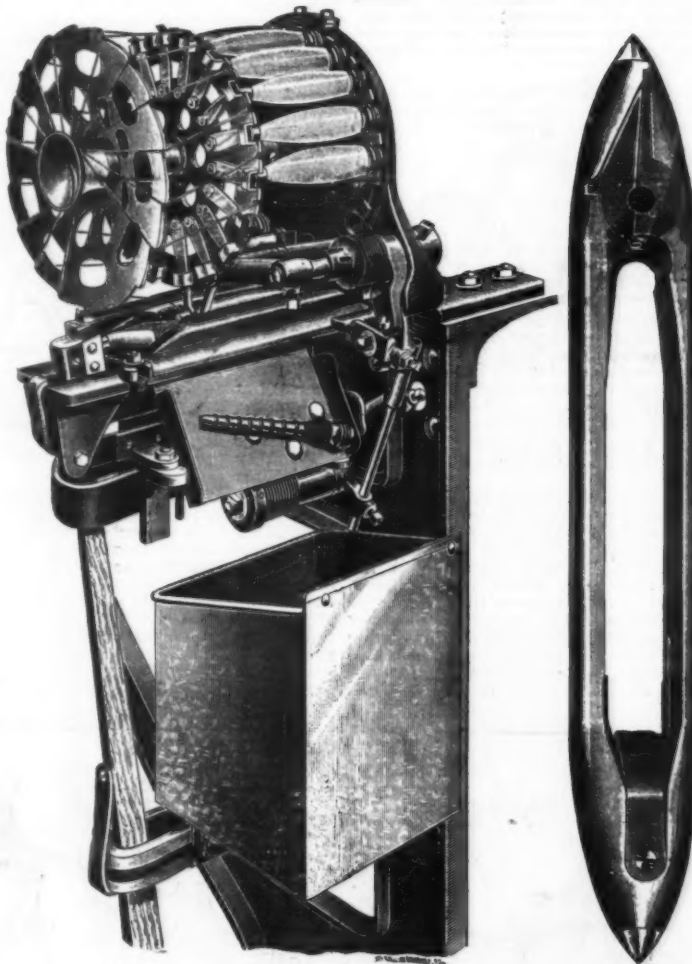
Involved in this apparatus are devices that permit

Empty Bobbin.

Steel Heddle.

DETAIL OF HOPPER MECHANISM.
(Other parts of loom erased.)
Shows fresh bobbin being inserted in shuttle, with empty bobbin falling into box.

PERSPECTIVE NORTHROP SHUTTLE.

THE NORTHROP LOOM.

the shuttle to vary in position to a certain extent as it necessarily does in practice, and yet prevent any damage if the shuttle should be abnormally misplaced. It is also arranged so that the loom will stop automatically should the hopper become exhausted, or should the shuttle eye become clogged so that it refuses to be threaded. All possible emergencies are provided for, and yet but few parts are used.

The expert may stamp the idea as impracticable, for the reason that if the weaver is not constantly near the loom he cannot prevent broken warp runs, or floats, which spoil the cloth, putting it into an inferior grade if allowed to continue uncared for. In reply to this we will say that this is provided for, and most efficiently, by combining with the filling changer a warp stop motion device that instantly stops the loom when a warp thread breaks. This combination relieves the weaver of all responsibility.

There are several kinds of stop motions developed for different uses, the one here referred to being made a part of the harness mechanism, each heddle serving as a drop wire to detect on the instant any severing of a warp thread.

Another combination made necessary on certain

styles of goods, where it is not feasible to allow a short end of filling to remain in the warp when an exhausted bobbin or cop is thrown out, is the additional use of a device to detect the proper moment when the supply of filling is nearly exhausted, and put in a new supply before the old bobbin or cop is entirely woven off, thus leaving the goods absolutely perfect.

The Messrs. Draper are running eighty looms on 28 inch cloth, 64×64, with five weavers, or with sixteen looms to each weaver. In the usual print cloth mill, weavers tend from four to eight looms. As Messrs. Draper have had weavers run twenty of their looms, it is safe to predict that instead of an average of six or seven looms to a weaver, as is usual on the old style, they can average more than twice as much. The present production of each weaver is an average of 96 50 yard cuts per week. The looms are running 190 picks per minute. There is no limit to the loom speed, as a loom has run on a test at 260 picks.

Another point of great value is the quality of the cloth produced. The warp stop motion guarantees perfection, so far as warp defects are concerned. It is simply impossible to compete with the quality of this cloth on ordinary looms. Then as the filling is changed with the loom in motion, thin places are almost entirely avoided. Seconds must of course be a scarce quantity, and weavers' fines almost unnecessary.

The production per loom is greater than ever before possible, for the reason that it is found to be entirely practical for the weavers to leave their looms running when they leave the mill at noon or night, and if the power be left on for the noon hour and an hour later at night, there is a very considerable gain. This is, of course, not a possibility with ordinary looms, as they have no devices to prevent poor work when not watched.

As far as loom fixing is concerned, the extra mechanism does not add appreciably to the fixer's work. By running one shuttle constantly the work of setting the pick is greatly eliminated; and all know that this takes up a large proportion of the ordinary fixer's time. Like every new machine, it is necessary to form an acquaintance with its mechanism.

There is yet another detail of great importance. As the warp stop motion prevents more than one thread being broken at one time, the effort of piecing in is very simple. Pickouts are substantially avoided on their looms.

The Messrs. Draper have at present orders from over twenty mills, the total being considerably over four thousand looms.

AN ALUMINUM TORPEDO BOAT.

DESCRIPTION OF AN ALUMINUM TORPEDO BOAT BUILT FOR THE FRENCH GOVERNMENT.*
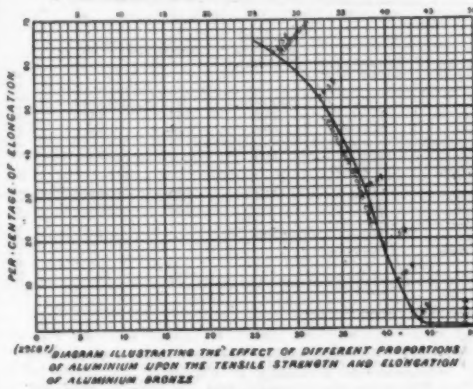
By A. F. YARROW (Member of Council).

As it seems not improbable that before very long aluminum and its light alloys may be available for those classes of construction in which lightness of material offers special advantages, it has been considered that a description of the aluminum second-class torpedo boat which we built last year for the French government might be interesting to the members of this institution, and I have now the pleasure to lay before you a few particulars.

About two years ago the French Admiralty determined upon introducing second-class torpedo boats in their navy, to form part of the equipment of large men-of-war, and they invited tenders for a sample vessel of this description. It is evident that lightness of construction is of paramount importance in a craft of this kind, not only because reduced displacement secures increased speed, but also because the boat has to be lifted and lowered by the tackle on board the vessel carrying it. Moreover, as these boats are placed high up on deck, any reduction of their weight increases the stability of the ship to which they are attached. The conditions laid down by the French

* Abstracts from a paper read before the Institution of Naval Architects.

authorities as regards speed, seagoing qualities and weight when lifted, were such as to render it scarcely possible to build such a craft on the usual plan and of the usual materials. We thought, therefore, it was a favorable opportunity to test the capabilities of a structure of aluminum, and our offer to build a torpedo boat of this metal was ultimately accepted. The French authorities gave us an entirely free hand, stipulating only that when the vessel was finished it should give complete satisfaction and conform to the conditions laid down.

As the result of numerous tests, we determined on using for the hull aluminum plates of 50 per cent. greater thickness than we should have adopted had steel been used; and as, approximately, aluminum is, bulk for bulk, one-third the weight of steel, it follows that the weight of the hull was reduced by one-half. I believe experience has shown that the scantlings adopted were suitable. Plates of pure aluminum seem to be very deficient in strength, and although they may be greatly strengthened by being rolled cold and

Fig. 1. TENSILE STRENGTH IN TONS PER SQUARE INCH

DIAGRAM ILLUSTRATING THE EFFECT OF DIFFERENT PROPORTIONS OF ALUMINIUM UPON THE TENSILE STRENGTH AND ELONGATION OF ALUMINIUM BRONZE

used unannealed, such treatment did not give all we required. Table I gives the result of four tests of pure aluminum plates. It shows that the ultimate strength ranges between 7 and 8 tons per square inch.

We had, therefore, to seek a light alloy in order to secure sufficient strength, and ultimately determined upon aluminum with 6 per cent. of copper. The strength of this alloy may be considerably varied during rolling. If "soft rolled," i. e., annealed after the last rolling, from 11 to 12 tons per square inch was obtained, with a large amount of elongation: if "hard rolled," the strength was greatly increased, but the material was found to be brittle. We finally adopted the 6 per cent. alloy, rolled to a medium extent of hardness, giving from 14 to 16 tons per square inch tensile strength, combined with an amount of toughness enabling the plates to be hammered into shape cold and to be bent to a sharp angle without showing signs of cracking. The framework of the hull consisted of angles of the same material. The plates and frames were all shaped cold, and we found no great difficulty in carrying out the work in a satisfactory manner; in fact, we had not a single plate or angle to condemn.

The results of tests made upon the plates used are shown on Table II. I would draw special attention to the high elastic limit as compared with the ultimate strength. All those portions subject to the action of sea or bilge water were riveted with aluminum rivets, and the remaining parts, such as the deck, not subjected to the action of sea or bilge water, were mostly riveted with soft iron rivets. In order to test the strength of riveted joints, and to judge of the water tightness of the joints, we made the experimental aluminum cylinder which is here. Its dimensions are:

Extreme length, 12 in.; outside diameter, 14¾ in. The barrel was made of aluminum, having 6 per cent. of copper; thickness, No. 12 L. S. G. The ends were of steel, flanged and riveted. The cylindrical portion was in three plates, lapped longitudinally and riveted to each other by two rows of aluminum rivets ¼ in. in diameter. The cylinder was filled with water, and the pressure pumped up to 100 lb. per square inch. It was perfectly tight at this. We continued pumping up to 200 lb. per square inch, when leakage became general, and upon reaching 300 lb. the longitudinal seam burst, due to the plate tearing away between the rivet holes. As evidence that aluminum can, with proper care, be worked cold, I have here a few specimens of articles made from it.

With reference to corrosion from sea water, we have tried a series of experiments, extending over 12 months, and we find, provided there is no galvanic action due to other metals being in contact with the aluminum, the corrosion may be taken at under 4 per cent. per annum for plates about ¼ in. thick, the surface being unpainted. At the same time it must be borne in mind that such a boat as I am describing should be

Fig. 2. TEMPERATURE IN DEGREES FAHRENHEIT

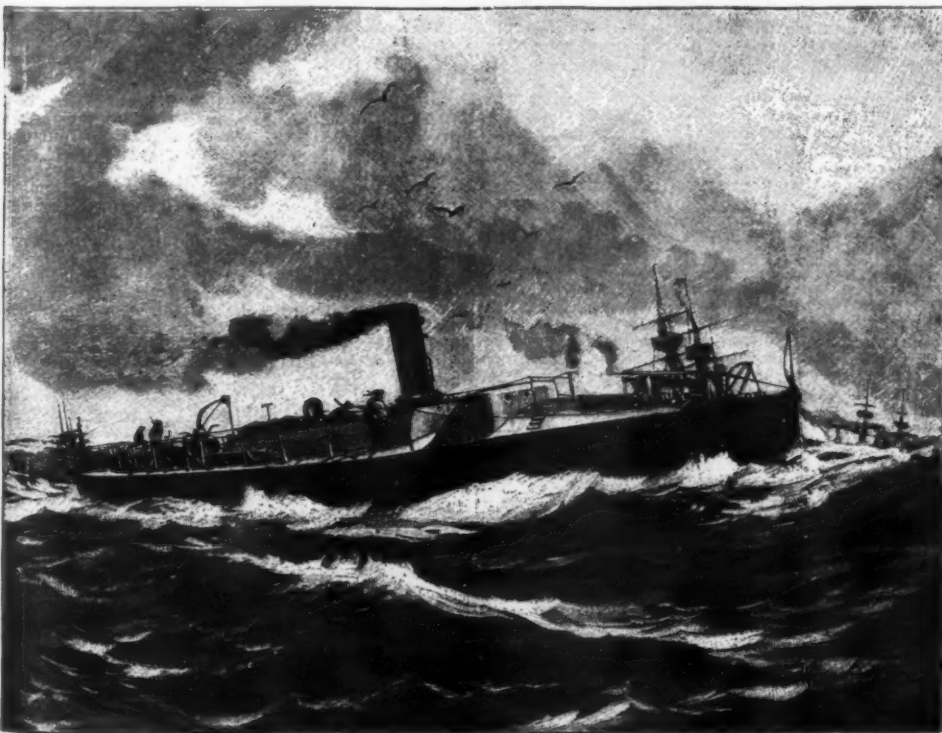DIAGRAM ILLUSTRATING THE EFFECT OF TEMPERATURE UPON THE STRENGTH OF ALUMINIUM BRONZE.
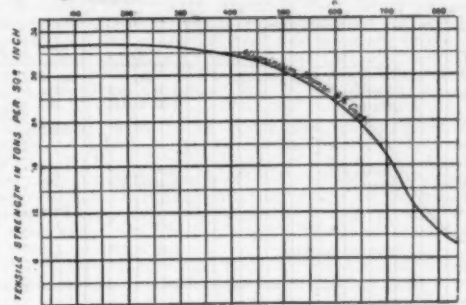
painted, and the paint used should be carefully selected, avoiding any that contains bodies which would have a direct chemical action on the plates. As further evidence of the effect of sea water upon aluminum, I would refer to the Vendenesse, a sailing yacht built of aluminum in Paris about 18 months ago. The report of it as regards corrosion is as follows: ". . . It has stood very well, excepting in a few places where copper fittings have been fixed in direct contact with the aluminum hull, which has produced a galvanic action. A similar action was produced when the boat was moored to a quay near another boat, the bottom of which was coppered, both being fastened to the same post by means of chains. With the above exceptions, direct contact with salt water has had no deteriorating effect."

The two great enemies to the use of aluminum are heat and alkalies. This material anneals at a comparatively low temperature, thus losing strength, while the alkalies act very rapidly upon it. Consequently any part likely to be subject to a considerable rise of temperature should not be made of aluminum, nor should it be used for a condenser where soda may be required for cleaning purposes. Aluminum at high temperatures oxidizes with exceptional rapidity. At low temperatures it does not oxidize so rapidly, and the film of oxide on the surface protects the metal from further action.

As regards the machinery of this little vessel there is nothing special to note, excepting that aluminum bronze and manganese bronze were used wherever practicable. No aluminum was employed except for the low pressure piston valve, for which purpose it seemed to answer well during the time the boat was in our hands. The engines were of the triple expansion type, and indicated on trial from 275 to 300 horse power. The boiler was of our usual type, with copper tubes.

Our contract with the French government was to construct a boat 60 ft. in length by 9 ft. 3 in. beam, which, with 3 tons load on board, should have a speed of 18¾ knots during a full speed trial of 2 hours, and which should not exceed 11 tons in weight, exclusive of the above load. The official trial took place on September 20, 1894, the average speed obtained during 2 hours, under the above conditions, being 20·558 knots. The boat was carefully weighed and found to be 10 tons. From this it will be seen that a speed of 1¾ knots beyond that contracted for was obtained, and the weight was 1 ton below the agreed maximum. In comparing this aluminum hull with one constructed of steel, the approximate saving in weight by adopting the lighter material cannot be taken at less than 2½ tons, which it must be admitted is a large percentage in a boat weighing, complete with its machinery, 10 tons. The machinery was found to weigh about 40 lb. per indicated horse power, including the water in the boiler and condenser. The vibration at all speeds was inappreciable. The details of the official trial are shown in the table. I may add, from information quite recently received, the French authorities are so exceedingly pleased with the boat, that they have in contemplation the building of several more, on the same plan, of aluminum.

With a view to render the light alloys of aluminum stronger and more suitable for the use of the engineer, there is a large field for investigation. Regarding the heavy alloys of aluminum, i. e., those where the aluminum forms a small proportion of the alloy, copper alloyed with aluminum stands very high, and is a formidable competitor with other bronzes. The properties of aluminum bronze, having different proportions of copper and aluminum, are shown by Fig. 1, for which I am indebted to the Aluminum Company, of Neuhausen. The figures given are obtained from specially cast bars, and therefore show a higher result than can be expected from test pieces attached to sand castings; but the curve indicates very clearly what I wish to show, viz., that an increase of aluminum, up to a certain point, augments the strength of the alloy, at the same time diminishing its elongation. I believe the tests demanded by many authorities for aluminum bronze propellers and other castings might, with ad-

AN ALUMINUM TORPEDO BOAT.

TABLE I.—EXPERIMENTS TO ASCERTAIN THE ELASTIC AND ULTIMATE TENSILE STRENGTH, &c., OF PURE ALUMINIUM PLATES.

Description.	Original.		Stress.		Ratio of Elastic to Ultimate.	Extension in 10 in.	
	Size.	Area.	Elastic per Square Inch.	Ultimate per Square Inch.			
	in.	sq. in.	lb.	lb.	per cent.	in.	per cent.
7¼ in. × 13 I.W.G. Lengthways	1.78 × .095	.167	9,691	18,560	57.7	2.36	23.6
Ditto, lengthways	1.78 × .094	.165	9,097	18,370	50.2	2.48	24.6
Mean =			9,689 = 4.8 tons	18,484 = 7.4 tons	52.4	..	23.1
Ditto, crossways	1.78 × .086	.167	12,575	17,665	71.3	1.32	13.2
Ditto, crossways	1.78 × .094	.165	12,727	16,533	77.0	0.55	5.5 flaw
Mean =			12,651 = 5.6 tons	17,099 = 7.6 tons	74.1	..	9.2

TABLE II.—RESULTS OF EXPERIMENTS TO ASCERTAIN THE ELASTIC AND ULTIMATE TENSILE STRENGTH, &c., OF ALUMINIUM PLATES, 6 PER CENT. COPPER, USED IN THE FRENCH TORPEDO-BOAT.

Description.	Original.		Stress.		Ratio of Elastic to Ultimate.	Extension in 10 in.	
	Size.	Area.	Elastic per Square Inch.	Ultimate per Square Inch.			
	in.	sq. in.	lb.	lb.	per cent.	in.	per cent.
2 in. × 20 in. × ½ in. Lengthway	2.00 × .109	.218	28,900	33,716	85.3	0.55	3.5
Lengthway	2.00 × .111	.222	32,480	36,117	89.8	0.58	3.8
Mean =			30,685 = 13.7 tons	34,416 = 16.4 tons	89.1	..	3.7
Crossway	2.00 × .109	.218	51,650	34,454	91.9	0.30	3.0
Crossway	2.00 × .112	.224	33,480	38,156	87.7	0.30	3.0
Mean =			32,565 = 14.5 tons	36,305 = 16.2 tons	89.8	..	3.0
Crossway annealed	2.00 × .112	.224	8,420 = 3.6 tons	26,210 = 11.7 tons	32.4	2.09	20.9

TABLE III.

Number of Run.	Steam in Boiler.	First Receiver.	Second Receiver.	Vacuum in Condenser.	Air Pressure in Stokehold.	Revolutions per Minute.	Speed.	Mean of Speed.
				in.	in.		knots	knots
1	186	72	12	26	3½	600.39	22.222	
2	186	72	12	24	1	508.30	19.585	
3	175	72	12	24	3½	503.40	21.877	20.608
4	175	68	11	24	1½	573.16	18.947	
5	186	65	11	24	½	586.30	21.438	
6	186	70	12½	25	½	591.45	19.585	

The trial on September 30, 1894, consisted of a continuous run of two hours' duration at the estuary of the Thames. Weather, calm. Number of persons on board, 17. Total load on trial, 3 tons. During the trial of two hours' duration the engines made 70,948 revolutions, being at the rate of 501·2 revolutions per minute, corresponding to a mean speed during the entire run of 20·608 knots per hour. The boiler made ample steam without priming, and the engines worked without any heating. The vibration was not appreciable.

TABLE IV.—Results of Experiments to ascertain the Resistance to Deflection under a gradually Increased Bending Stress. Size of Bars = 1 In. Square. Distance between Supports = 10 In.

Description.	Stress.		Ratio of Elastic to Ultimate.	Deflection at			
	Elastic Total.	Ultimate Total.		2000 Lb.	4000 Lb.	6000 Lb.	8000 Lb.
	lb.	lb.	p. c.	in.	in.	in.	in.
Cast aluminium bronze	4100	5442	68.5	.030	.096	.200	.688
	4100	5176	80.1	.022	.065	.207	.688
Mean	4100	5319	49.3	.031	.096	.205	.938
Cast manganese bronze	3900	8022	45.6	.027	.110	.450	.213
	3900	7988	48.9	.024	.100	.464	
Mean	3900	7995	48.7	.025	.100	.457	
Cast gun-metal	2180	3784	56.2	.041			
	2160	3786	57.1	.045			
Mean	2170	3785	57.0	.043			
Cast aluminium	2150	3069	70.1	.040			
	2070	2641	78.4	.044			
Mean	2110	2955	74.2	.042			
Cast iron	3981	3991	100.0	.027			
	3617	3627	100.0	.031			
	3605	3605	100.0	.032			
Mean	3608	3608	100.0	.030			
Cast iron	3786	3786	100.0	.049			
	3443	3443	100.0	.039			
	3402	3402	100.0	.034			
Mean	3544	3544	100.0	.041			
Mild steel	3560	6784	52.6	.019	.119	1.09	
	3560	6696	53.0	.020	.117	1.09	
Mean	3560	6735	52.8	.019	.118	1.09	
Mild steel Forged from 3-in. round steel	4670	9059	51.6	.018	.045	.07½	.824
	4700	9068	59.3	.020	.046	.412	
Mean	5135	9082	50.9	.019	.045	.948	

TABLE V.—Experiment to Test the Effect of Differences in Diameter on Percentage of Elongation, the Length of Test-Pieces being Constant, and Cut from the same Bar of Mild Steel.

Dimensions.	Area.	Reduction of Area at Fracture.	Extension. On 2 In.	On Original Area. Maximum Stress.
diameter in.	sq. in.	per cent.	per cent.	tons per sq. in.
0.248	0.0483	71.6	24.0	25.84
0.502	0.1979	67.3	28.8	24.76
0.744	0.4847	67.0	42.0	24.55
0.994	0.7760	67.1	47.0	24.39

vantage, be modified so as to admit of an alloy being used having greater strength with reduced elongation.

Owing to the high steam pressures (and consequent high temperatures) now demanded, it may be of interest to know to what extent aluminum bronze loses strength as the temperature rises. The curve (Fig. 2) shows the diminution of strength with rise of temperature.

Table IV illustrates the results of experiments to ascertain the resistance to flexure, under a gradually increasing load, of eight different metals and alloys, the distance between the supports being 10 in., and the bars tested being 1 in. square. From this it will be seen that aluminum bronze at the high strains maintains its form exceptionally well, and consequently is specially suitable for some purposes. I may, however, add that the Manganese Bronze Company state they are prepared to supply a bronze of considerably greater strength than the manganese bronze specimen tested. The latter was of metal where a considerable elongation was demanded, involving a weaker material. The Manganese Bronze Company state that they can give a material of 33 tons breaking strain with 15 per cent. elongation on 2 in. in test pieces cut from the castings. Having in view that any increased percentage of elongation results in a weaker material, I would submit that 15 per cent. elongation in this class of bronzes should be the maximum asked for by engineers, more particularly if this material is substituted for cast iron, which has practically no elongation; in fact, for many purposes I believe 10 per cent. elongation and a stronger material would be even better.

Referring to the tests made of different materials in the last table, I have had photographs taken from those bars and a few others; these illustrate to some extent the structure of the metal. These, enlarged about 1,400 times, will now be shown on the screen, i. e., the image on the screen is 1,400 diameters of the original. Some of the photos are from the actual rough fractures, and some from surfaces which have been polished and then etched. For these very beautiful photographs I am indebted to my friend Mr. Haddon.

I would here point out a difficulty in dealing with tests of material. There seems to be no standard diameter, nor standard length, for test pieces. Under these circumstances it is very difficult to compare results. For example, if a given length of test piece is specified irrespective of diameter, the test is of little value for elongation, because as the diameter increases the elongation increases. This is clearly shown by Table V. Four specimens were prepared from the same mild steel bar and turned down to ¼ in., ½ in., ¾ in., and 1 in. in diameter, all 2 in. long, and the elongations, it will be seen, are 24, 36, 42, and 47 per cent. respectively. It will be noticed that the reduction of area at fracture is practically constant, and I would submit that this, in some cases, is a more reliable guide as to ductility than elongations, unless some common basis for estimating elongation is agreed upon. As regards calculating the limit of elasticity, no two authorities appear to agree upon the mode in which it should be estimated. I wish it to be understood, as regards elastic limit, I do not propose to fix a given standard for all materials, but for similar materials, possibly, some uniformity might be arrived at. Certainly, as it is now, there seems to be a divergence of practice which is very confusing. I would venture to suggest that it would be very convenient if a common basis for tests of materials were agreed upon, so that results might be more readily compared than is possible under existing circumstances.

THE SPLIT TUBE SYSTEM.

A CLEVER, though simple, invention is Pease's system of interlocked split tubing. In this strips of iron, steel, phosphor bronze, or other metal are bent into a tubular shape by special machinery, the edges being sufficiently far apart to allow two other pieces to enter, as shown in our illustration.

By this means a firm yet cheap and simple construction is obtained, which may be used either horizontally or vertically, i. e., for flooring, walls, or columns. Usually the insides of the tubes are filled with concrete; but when an air space is required, the part where the two tubes overlap is left empty. As the concrete supports a great part of the weight, the iron may be very thin. A strip 11 in. wide, made of 2 in. tubes, No. 24 B. W. G., or, say, ¹⁄₁₀ of an inch, supported 17½ tons on end without bending, and a strip of the same size, but made of iron No. 8 B. W. G. thick, carried a ton per square foot of surface. This system is shown by the sections below, and is well adapted for the construc-
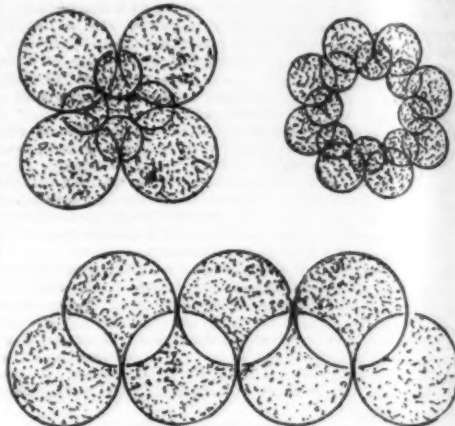

SPLIT TUBE AND CONCRETE CONSTRUCTION.

tion of columns for various purposes. The outer tubes can be of phosphor bronze or other metal, either taper or parallel, and they can be held together by smaller tubes of iron.

TO "FALL" A CHIMNEY.

IT is easy to fall a chimney, if you know how. Joe Smith, a steeple-jack, has successfully performed the feat for the Corporation of Bury, on a brick chimney, 120 feet high, 10 feet square at the base, and 5 feet 6 inches at the top. About 54 cubic yards of brick were removed from the base of the chimney, cornerwise, facing the place it was desired to land the debris, and blocks of wood, 6 inches square, put in the opening. Inflammable material was placed around the blocks, and soaked with tar and oil. After an iron
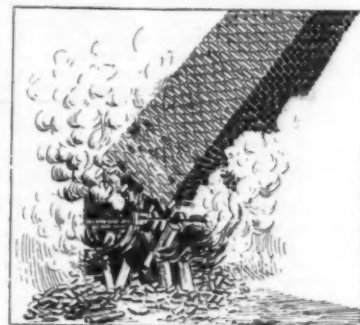
belt had been placed around the chimney a few yards from its base, to prevent bulging, the fire was started, and in twenty-five minutes the bricks were lying on the ground in the place prepared. The illustration is reproduced from the Surveyor, London.

THE MANUFACTURE OF STARCH FROM MAIZE.

By J. KRIEGNER.

THE first stage in the manufacture of starch—the liberation of the starch cells from the substances in which they are embedded—is effected in four operations.

1. Softening of the maize in water.
2. Crushing and grinding of the softened maize.
3. Mechanical separation of husks and germs.
4. Solution and separation of the gluten.

The softening process is conducted in wooden tanks of about 25,000 kilos. capacity, in which the unground maize is treated with water as hot as possible (60° to 66° C.), consistent with non-gelatinization of the starch. After 12 to 24 hours the steep liquor is removed and renewed daily during 3 to 4 days, the temperature being lowered each time, so that it finally stands at 32° to 38° C. The softened mass is subsequently ground between rotating stones or rolls, or a combination of the two. In the first case, ordinary flat millstones, set sharp and placed closely together, are employed, and the water added during grinding is so regulated that a thin, soft pulp, quite free from grits, may be obtained. Too coarse, or bad milling, results in loss of starch; while excessive grinding has the same effect, and in addition leads to the production of an inferior grade of starch, owing to the excessive disintegration of the fibrous portions of the grain, whereby their final separation is rendered more difficult. Under favorable conditions, a mill 3 feet in diameter will grind 25 tons of maize in 24 hours; but this efficiency may be doubled by employing in conjunction with the mill a system of rollers. In an arrangement of this kind, which the author particularly recommends, the maize is first crushed between fluted rolls, then pulped in an agitator provided with rapidly rotating blunt beaters. The germs which rise to the surface at this stage are skimmed off and the remaining pulp milled as usual.

After milling, the starchy portion of the pulp is separated from the coarser impurities (husks, etc.) by washing the mass on rapidly vibrating, obliquely mounted sieves (3 feet wide, 6 feet long) covered with

fine silk gauze (120 to 160 threads per inch). The manner in which the washing water is supplied to the sieves is a matter of some importance. The usual plan, as shown in the accompanying drawing, in which A A represents the sieve surface, B B and D gutters for conveying starch pulp and water respectively, is regarded by the author as unsatisfactory. Much of the water falling on the sieve at d passes right through the gauze instead of flowing over its surface. This may be partly obviated by placing a lath immediately below the point where the water falls; but the best results are obtained by supplying water to the under surface of the sieve by means of shallow troughs, h and g. Although the above form of sieve possesses certain advantages over the rotatory cylindrical form, there is no doubt that in the latter a far more uniform application of the wash water and more perfect washing are possible. In one form, which has been largely adopted, the inner periphery of the cylinder is fitted with a continuous spiral diaphragm, which compels the starch mass, during the rotation of the apparatus, to travel over every portion of its surface.

For the purpose of regulating the flow of the pulp to the sieves, the inclusion of taps or valves in the pipe system is not advisable, on account of the stoppages likely to occur. A plan that has been found to work well is to pump the pulp into a small tank, through the bottom of which slide a number of open pipes, one to each sieve. By sliding these pipes up or down, the flow may be adjusted to a nicety. The starch milk from the sieve is preferably divided into two parts, the richer (sp. gr. 6° B.) and poorer portions (2° B.) being collected and worked up separately.

The remaining operation, the solution of the gluten which cements together the starch cells, is exclusively effected by chemical means, either caustic soda or sulphurous acid being used. In the first instance, about 0·1 per cent. of alkali is added directly to the starch milk, which is then ready for immediate further treatment. In the acid process, the acid is employed at the very outset, about 0·4 per cent. of SO_2 being added to the steep liquor. It serves not only to dissolve the gluten, but plays the part of a disintegrating, preservative and bleaching agent.

The final purification of the starch by washing, deposition, etc., and the drying process are carried out in much the same manner as in Europe. About 85 per cent. of the crude starch is recovered by these processes, the remainder being carried away with the gluten. Starch produced by the acid process is usually of a fine white color and yields a thin, elastic paste. On this account it is preferred for glazing, loading textile fabrics, etc. On the other hand, alkaline starch is inferior as regards appearance, but gives a much stiffer paste, which fact renders it more suitable for use in laundries, paper bag and box making, etc. These peculiarities may be referred to the presence of traces of acid or alkali in the respective starches.

The gluten (precipitated by the addition of an acid when the alkaline process has been used) in the waste liquors is recovered by filtration, dried and coarsely ground. In this state it forms a valuable cattle food, containing, as it does, albuminoids, 30 to 35 per cent., the same amount of starch; fat, 8 per cent.; water, 10 per cent. Another by-product, known as "slop," consists of the coarser portions of the grain (husk, etc.), and is usually disposed of in the moist state to farmers,
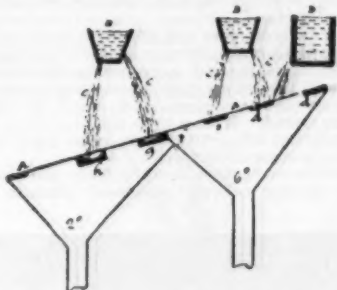
etc. Or, if this is not possible, the slop may be dried. 100 parts of maize yield on the average: anhydrous starch, 46·5 to 52; gluten meal, 18; dried slops, 18. In the selection of the raw material for starch manufacture, special stress is laid on thinness of husk, smallness of germ, and a high percentage of starch.

The Recovery of Oil from Maize Germs.—Maize germs contain about 50 per cent. of oil, which may be readily extracted by grinding and hot pressing the dried germs. It is, however, worth while doing this only in larger installations (consuming 25,000 bushels of maize and upward). In such cases it is usual to separate the germs during the crushing process in the manner already indicated. Crude maize oil has a specific gravity of 0·917, is yellowish-red in color, and possesses a characteristic odor of maize. On standing, it deposits a small amount of granular fatty matter.—Dingler's Polyt. J., 1895, 295, 39 to 42.
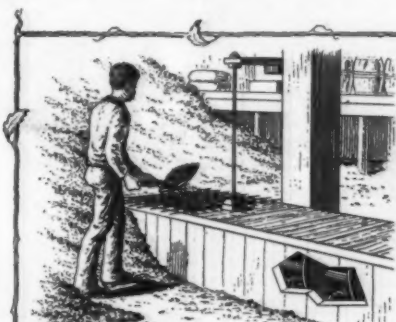
MANUFACTURE OF ROCK WALL PLASTER.

THE illustrations accompanying this were taken from the plant of the Rock Plaster Company, Hoboken, N. J. The plaster is composed of plaster of Paris, clay, cattle hair, lime, sand, asbestos and a retarding agent which prevents the material when mixed from drying too quickly. The sand is brown in color and comes from Prince's Bay, Staten Island. The clay comes from Perth Amboy, N. J., already washed and free of gravel. The sand, before being mixed with the other ingredients, passes through a drying and screening process. A certain quantity is then weighed out and placed with the other parts into a machine which thoroughly mixes the material together. The plaster is then passed into bags ready for the market. The sand is carried to the drier by means of a screw conveyor. The trough in which the screw revolves is 100 feet in length and about 18 inches in height and width and made of wood. The thread of the screw is about 12 inches in diameter and the flights about 12 inches apart. The sand is shoveled into the end of the conveyor, the screw carrying it along at the rate of about 50 feet per minute. About 4 tons an hour is carried along by the revolving screw to the end of the trough, where it falls down into a chute and is immediately taken up through an elevator by means of a cupped belt and dumped into another small screw conveyor 10 feet in length and 18 inches in height and width, which passes the material along, dropping it down into a circular revolving drier.

The drier is made of boiler iron, about 18 feet in length and about 4½ feet in diameter, and revolves at the rate of about 13 revolutions per minute. A shaft passes through the center of the cylinder, projecting from which are a number of arms, which are bolted at the ends to the shell. Between the arms are a number of steel fans about 2 feet in length and about 10 inches in width.

The cylinder revolves on the inside of a hollow brick compartment about 30 feet in length, about 6 feet in width and about 10 feet in height. Underneath one end of the cylinder is a 6 × 6 foot furnace, in which a hot coke fire is kept burning for heating and drying the sand as the drier revolves. The cylinder is slightly inclined, having a drop at one end of about 18 inches. The sand, as it drops down into the drier, is carried or tossed around the hot revolving cylinder by means of the fans. By the time the material reaches the end of the cylinder it is perfectly dry. The heat from the furnace passes through the drier at the end and out through the chimney. The dry hot sand drops down from the cylinder into a hopper, where it is passed into another screw conveyor which carries it along to an elevator, which in turn takes up the sand by means of cups to the top of the manufactory, where it passes into a circular screen. The cups are attached to iron bars about 2 inches in width and about 2 feet in length. The bars are connected at the ends every 2 feet apart to sprocket chains which carry the cups, containing about one quart of sand each, to the screen. The screen is about 6 feet in length and about 2 feet in diameter and revolves at the rate of 20 revolutions per minute. The sand falls through the fine meshes of the screen, leaving the gravel, which passes off at the end into a chute and down into the yard below, where it is sold to contractors.

About 4 tons an hour passes through the screen and drops down into a 25 ton hopper, from which it is run out into an automatic scale below, where the required quantity for mixing is weighed.
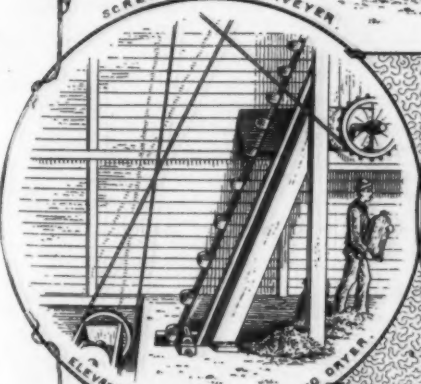
The clay, which is hard and chunky, is broken up by an attendant and shoveled into a rotary grinding mill and pulverized. The ingredients, consisting of lime, plaster of Paris, sand, etc., which amount to
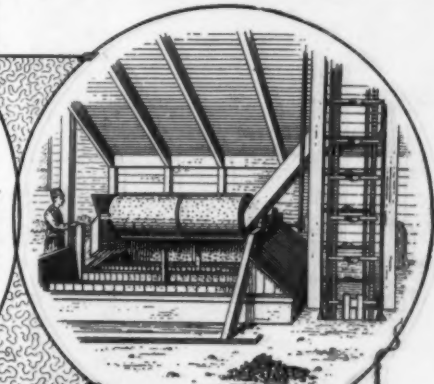

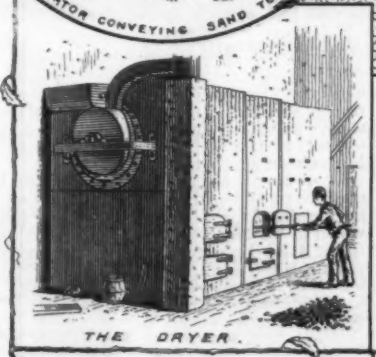WEIGHING SAND

SCREW SAND CONVEYER
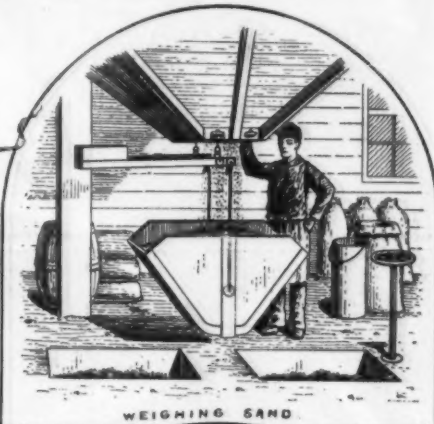
ELEVATOR CONVEYING SAND TO DRYER
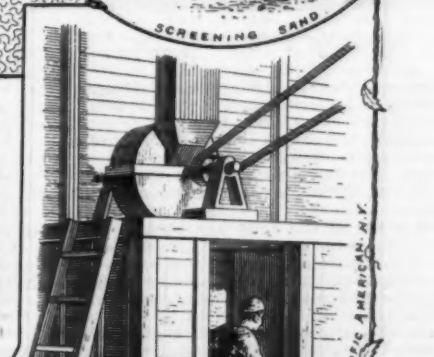
MIXING AND BAGGING MACHINE

SCREENING SAND

THE DRYER.

SECTIONAL VIEW OF DRYER.

CLAY GRINDER.

MANUFACTURE OF ROCK WALL PLASTER.

about one-half ton in weight, are placed in the hopper below the scale and dropped down into the mixer, the apparatus by means of a number of arms or paddles inside thoroughly mixing the materials up in about three minutes. The mixed plaster is then run out of the apparatus into a receiving hopper below and packed into bags weighing 100 lb. each. Fifteen hands turn out about 55 tons of plaster per day.

The plaster when used is mixed with from two to three parts sand, the sand and plaster being thoroughly mixed together before adding water.

BELL RINGERS.

EVEN to the faithful, the legendary voyage of the bells to Rome passes to-day almost unperceived. For there is less ringing of bells than there was formerly, especially at Paris, and the full peals of Easter and Christmas have themselves been sacrificed in part.

The republic has often been accused, but wrongly, of having interfered with the free exercise of worship. The canons of various councils forbid the use of bells for laic purposes, save in the cases of peril or absolute necessity, and a decree of the council of state of 1840 limits the intervention of the local police to the inter-

METHOD OF RINGING A BELL.

diction of bell ringing contrary to good order and public safety. The third republic has not admitted such jurisprudence, and a law of April 5, 1884, recognized the right of mayors to use bells in certain definite cases.

A few months later on a ministerial decree made regulations concerning religious and civil ringings.

RINGING THE ANGELUS.

For some reason or other, the ecclesiastical authority cannot now have bells rung before four o'clock in the morning and after nine o'clock at night, from Easter until October 31, nor before five o'clock in the morning and after eight o'clock at night from November 1 until Easter. Exception is made for Christmas eve. As may be seen, there is nothing vexatious about such restrictions.

But the music of the bells has become very dear music, and that is the sole cause of its decadence.

The setting in motion is easy. The bell is fixed by its upper ring to a strong oak beam provided with trunnions that slide upon fixed bearings or roll in a system of sectors. As a general thing the weight of the beam is light as compared with that of the bell, and the center of gravity of the whole is so calculated that the clapper shall strike the upper lip of the bell and immediately fall, allowing the vibrations to develop in their entire amplitude. In the south, where bells are of light construction, the beam balances almost the entire weight of the bell. It is then the lower lip that strikes the clapper, which it raises along with it to the end of its travel. The clapper thus remains adherent to the metal that it has struck and the vibrations are sensibly muffled.

Whatever be the method of suspension, however, the

manner of ringing is the same. At each extremity of the beam, and upon its two faces, is fixed a lever, which, on being pushed with the foot, causes the entire system to swing. Each man thus produces a work double that obtained with the rope, and huge masses may be set in motion. Although an error, it is still believed that starting from a certain weight one ought to discontinue the ringing of bells in peals. In this regard there is no limit, provided the belfry be capable of supporting the concussion. The great bell of Saint Sulpice, represented in one of our engravings, weighs 13,200 pounds and is maneuvered by four men. The bell of Notre Dame weighs 35,000 pounds and requires eight men. Small bells of 6,000 pounds are maneuvered by two men.

As may be seen from one of our engravings, the art of ringing bells is a genuine gymnastic exercise. Standing upon a beam and grasping handles fixed to the framework, the ringer pushes the lever, and is obliged to undergo violent contortions in order to follow the bell in its travel. With a little muscle it is nothing to ring a bell, but when the latter forms part of a chime the thing is entirely different.
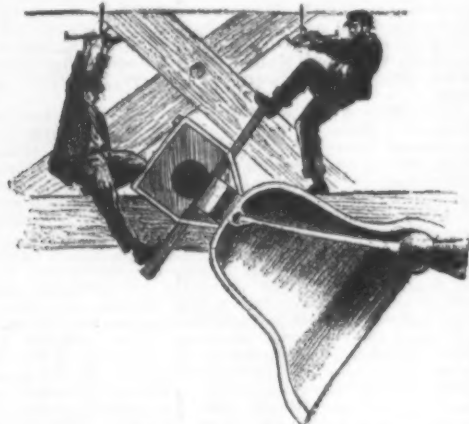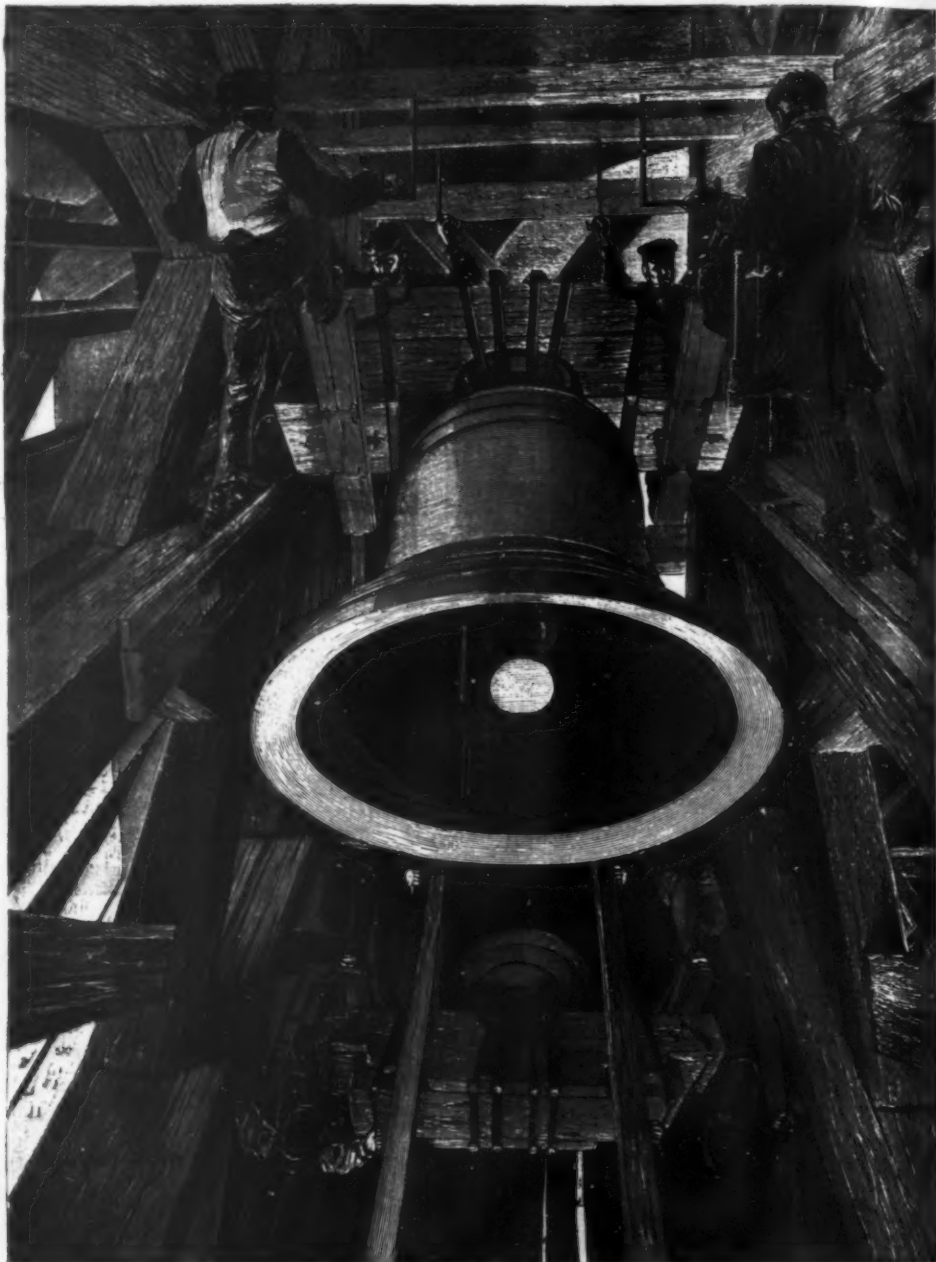
Before the revolution, certain large parishes, Saint Sulpice among others, possessed gamuts of eight bells. At present four are regarded as sufficient—the large, medium, intermediate and small bell, each giving a different note with two intervals of a tone and half tone. The order of the successive sounds produced by three bells at the least ringing a full peal is called a chord. There are six principal chords that bell ringers have transmitted from time immemorial; the discord, the belle enfant, the tintentipot, the romaine, the rebours and the sonnerie des morts.

If it be reflected that, in the short time necessary for the clapper to strike the two lips of a bell in a peal, the three other bells must give their distinct note in succession, the difficulty of pushing in measure will be understood. The sounds increase with such rapidity that the least retardation of one bell with respect to the other suffices to make the two bells give their note at the same time. It is then almost impossible to catch up, and if the peal be not stopped, the cacophony becomes general. The problem becomes complicated when it is desired to make variations, that is to say, to pass from one air to another in the course of the ringing. It belongs to the "accordant" to regulate this concatenation of sounds, and to direct the ringers, who are simple maneuverers. Accordants were still learning their business thirty years ago. Some pious melomaniacs made a request to have themselves

inscribed in the parishes as apprentice ringers, and, not being able to study in the belfry every day, they repaired for exercise to the loft of the Hildebrand foundry, where a set of bells was obligingly put at their disposal. After five or six years of pushing, the most capable became accordants. None of these amateurs was remunerated. It was a much envied honor to command a bell in a large parish.

These elevated recreations are now no longer appreciated. Amateurs of music have turned toward more portable instruments, and, in measure as the old accordants have become deaf, the churches have had to replace them by any mercenaries whatever.

The peal lasts about a quarter of an hour. For bells of a certain weight, 20 cents is paid to the pushers and 50 to the accordants, say 70 cents per bell of four men. This makes the full peal cost in the neighborhood of three dollars.

It may be readily seen what the expense would now be of the eighteen peals formerly reglementary every Sunday at Saint Sulpice and in many other parishes. That is why we hear all the bells rung only at the three or four great festivals of the year. On Sunday two peals are made to suffice, one at the beginning of mass and the other at the beginning of vespers. On

RINGING THE BELLS AT SAINT SULPICE.

week days the curate's mass simply is rung. The head ringer, standing under the bell, pushes the clapper slowly with his hand, enveloped in a vortex of sonorous waves that add one degree more to his deafness. He rests on ringing the Angelus.

There are, therefore, too few working hours to allow accordants to learn their business, so we find no more apprentice ringers. Paris is perhaps that city of the world in which the poorest ringing is done. The parish of Saint Laurent alone has preserved good traditions. Not so well, however, as the ringers of Bagnolet, since it is the latter that have the confidence of the Hildebrand establishment for the "first" of the bells leaving its works.

Before long the last of the ringers will have their knell tolled. Lost in their towers, they are finishing their life in bewailing the chimes of the year gone by, and the picturesque figure of the ringer of Saint Sulpice that Huysmans has so charmingly presented in La Bas will soon rejoin the shade of Quasimodo in the legend.—L'Illustration.

LIVERPOOL is the most densely populated city in Great Britain, having a population of 97.9 per acre or 114 per acre excluding the docks and quay.

CHEMICAL INDUSTRY AT THE CHICAGO EXHIBITION.*

THE author of this report, who is professor of chemical technology at the Royal Technical High School of Berlin, in his visit to the United States in the summer and autumn of 1893, set before himself two objects—a study of the products of chemical industry exhibited at Chicago and an examination of the present state and future prospects of chemical manufactures in this country.

While acknowledging with gratitude the obliging readiness of individual exhibitors, and of those connected with American manufacturing establishments, to afford information, he makes more than one significant allusion to defects of management which marred the Chicago exhibition for thoughtful students of it as a serious display of the world's work—the imperfection with which much of the pretentious plan was carried out, the difficulty of finding many things scattered among the huge buildings, the uselessness of the official general catalogue, the poor light in large portions of the space devoted to exhibits, etc. He found but three countries at all worthily represented in the field of chemical industry—namely Germany, the United States, and Japan—and felt most interest in the contrast presented by his own country, of originally limited resources, but now possessing the most highly developed chemical manufactures, with the United States, gifted by nature with resources in the way of raw material wonderful in extent and variety, but barely beginning to develop and utilize them.

Some very important branches of industry dependent upon chemical principles, including some that have become well established in this country and owe much in the way of improvement to American skill and enterprise, are excluded from consideration in the report. Thus metallurgical processes, and all those processes more or less closely connected with food, such as the preparation of sugar and starch, brewing, distilling, etc., are omitted. The subject is treated under three main heads—fuel, inorganic chemical products and chemical products of organic origin or character.

Under the first head there is a condensed account of American petroleum, its varieties, distribution, extraction, and refining, including some comparison with the treatment of the analogous Russian product, and some notice of its special value as heat producing fuel in certain manufacturing operations. Attention is drawn to the mineral oil distilled at Sydney from the bituminous shale of New South Wales, this shale being reported as existing on quite a large scale.
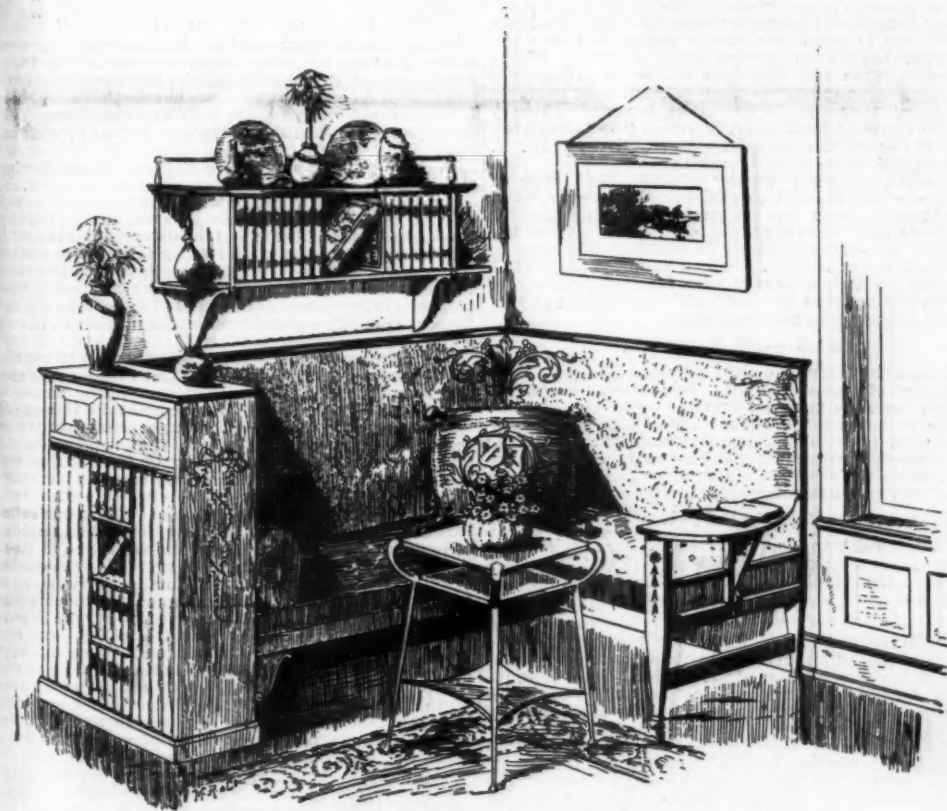
In noticing the abundance of coal in the United States and its immense importance for the future, with which the author was greatly impressed, he finds it least troublesome to mention the States only (nine in number) in which workable coal has not been found. He observes the less depth of most American coal mines than of those in Europe, and hence in part the superior cheapness of the product—also the freer choice between anthracite and bituminous coal over a large part of the country. He comments on the occurrence of the most valuable coal beds in the regions comparatively near the Atlantic coast, while the coal of the interior of the continent is for the most part of more recent age and poorer in quality, and concludes from this difference that to the Atlantic States belongs, in the main, the future of chemical manufacturing on the great scale. He did not see any sign of efforts to secure smoke consumption, and was surprised to find so little progress toward saving the by-products (tar and ammoniacal liquor) of coking bituminous coal, as is now quite successfully done in the Rhenish provinces and in Silesia. He understands that the great extension of electric lighting, and the general use in the larger cities of the United States of " water gas " * instead of coal gas proper for illuminating purposes, offer little prospect of tar and ammonia products growing in importance in the future, although the Solvay process soda works at Syracuse, N. Y., have started an experimental set of Semet-Solvay coke ovens, saving the by-products. Hence the outlook for American competition in the multifarious chemical industries based upon the constituents of tar does not at all alarm the German observer. It would seem, however, that the enormous demand in this country for fertilizers of all kinds, including the nitrogenous, ought to lead the managers of the great Pennsylvanian and West Virginian coke works to look carefully into this question of saving the by-products obtainable by some of the more modern types of ovens. If the day has not yet come, or perhaps may never come, for rivaling here the great German factories for coal tar colors, medicinal agents, artificial perfumes, etc., it does not seem certain that the crude benzene, toluene, anthracene, phenol, and the like, might not be made with profit on a large scale in America, by first distillation of tar, if the tar itself were saved in adequate quantity to build up a large business.

The reporter comments, as so many others have done before him, on the reckless destruction of wood in the great forest-covered regions of the United States. He notes the fact that the dry distillation of wood, yielding acetic acid, methyl alcohol, and acetone, is carried on in this country; but this industry was not represented at the Chicago exhibition, and he apparently did not hear of some interesting peculiarities which American works have developed in connection with it.

As respects the prime natural materials for chemical industry on the great scale, Dr. Witt does not consider the United States so highly favored as Europe. He notes the fact that this country is now the greatest consumer of sulphur (as such) in the world, pointing out that in 1889 there was imported from Sicily three times as much as was taken by England in the same year, some moderate amount coming in from Japan at San Francisco, a few hundred tons only of domestic sulphur being supplied by California, Nevada, and Utah, and none yet furnished by the great Louisiana bed in Calcasieu Parish, which is so far known only by borings. The reporter seems to look for little increase in the use of pyrites for making sulphuric acid, observing that only Massachusetts and Virginia furnish pyrites in any important quantity, but on this point he probably underrates the influence of present commercial conditions favoring the use of native sulphur, and the possibilities of the future in the way of larger supply of pyrites (as from Georgia, New York, and some of the Western States) under the stimulus of increased demand. He not unnaturally speaks of rock salt in the United States as a small affair in comparison with the vast European deposits at Stassfurt, Wieliczka, etc., but hardly does justice to the extent of production of American boiled salt for the country at large, though he describes with interest the many square miles of shallow wooden tanks at Syracuse for evaporation of brine at atmospheric temperature, and notices the exhibit at Chicago of boiled salt from the Great Salt Lake of Utah. Mention is made of "abraumsalz" (kainite) as shown from the Louisiana salt bed on Petit Anse Island, but it may be questioned whether there was not some mistake about this. It is conceded that American limestone is abundant and widely distributed. Manganese ore is said to be chiefly used in this country for decolorizing glass, but this statement seems to ignore the great scale on which it is now called for by the large steel works. It is stated that large quantities of oxide of manganese in the form of " Weldon mud" are imported into the United States and used in coloring tiles and terra cotta blocks in imitation of, or to harmonize with, "brownstone." Notice is taken of the native carbonate and sulphate of soda from Wyoming as interesting American specialties. The only worthy exhibits of crude chemical materials from Europe were those of English salt and German (Stassfurt) potash and magnesia compounds.

There was practically no general display at Chicago illustrative of the production of acids and alkalies on the great scale. Notice is taken of the extensive use in America of Sicilian and "regenerated" sulphur for making sulphuric acid, and the consequent greater freedom of the acid than in Europe from arsenic, making easier the production of pure hydrochloric and nitric acids. The great demand now for bicarbonate of soda, growing out of the widespread use of "baking powders" and the large consumption of soda water, and the more frequent use than in Europe of carbonate of soda instead of sulphate of soda for glass making, are facts shown to bear strongly on the question of the alkali industry becoming established on a great scale in America. Few facts in regard to chemical manufactures are more remarkable than that this has not yet taken place. Notice is taken of the ammonia soda works at Syracuse, N. Y., operating under the Solvay patents, but making no separate exhibit of the product, which was shown in the French department, and very favorable comment is made on the cryolite soda works of Natrona, Pa., the special raison d'etre for which is taken to be the large demand in the United States for aluminum salts for paper making, dyeing, etc., with relative scarcity of bauxite; the Natrona establishment is spoken of as a good example, "the only one in America," of an undertaking in the way of large chemical manufacture well devised to meet actual conditions, complete in itself, and working up all by-products. Dr. Witt does not seem to have heard of the large alkali works which are being built at Saltville, in Southwestern Virginia, at which it is proposed to operate on both the Leblanc and the ammonia soda plans. An extended account is given of the exhibit made at Chicago in the English section by the great "syndicate" (formed in 1890), known as the United Alkali Company, the largest joint stock chemical manufacturing company in the world, with a total capital of nearly £9,000,000 sterling, uniting 45 great chemical factories, 3 salt works, 2 soap factories, and 1 resin refinery. Attention is drawn to several of

SUGGESTIONS FOR CORNER DECORATIONS.

From Moderne Innen-Decoration.

the special products of this company, such as the very convenient caustic soda in powder (pulverized in closed mills, excluding the air), the "crystal carbonate of soda" (crystallized hot, with but a single molecule of water of crystallization), which has the advantage over ordinary soda crystals of greater concentration and offers an equal guarantee of purity, the sodium chlorate (with greater solubility than that of potassium chlorate) for print works, the barium chlorate giving aniline chlorate by interaction with aniline sulphate, the sodium manganate for use as a cheap disinfecting material, the finely pulverulent chromium trioxide in airtight packages for Bunsen batteries, and the regenerated sulphur from the Leblanc process, of which 40,000 or 50,000 tons a year are produced, much of which finds a market in the United States to be again converted into sulphuric acid.

Ammonia soda appeared at the exhibition not only from the Solvay works in France (Varangeville-Dombasle), but from English and Russian establishments.

Under the head of materials used as manures it is remarked that Germany holds essentially a monopoly of potash salts ; that the United States depends for nitrogenous material upon South American nitrate of soda and European sulphate of ammonia, neglecting the advantages offered by modern coke ovens for saving the nitrogen of coal, but that to this country must be conceded the first place in the supply of phosphates.

The reporter fully recognizes the great importance of the phosphate deposits of South Carolina and Florida, especially the latter, which he visited and gives some description of.

The extent and importance of the American manufacture of glass are noted, though this industry was very poorly represented at Chicago. The reporter was impressed by the good results of using (since 1880) furnaces fired with natural gas, and also with artificially prepared gaseous fuel ("generator" gas), the high and easily controlled temperature of these furnaces having regenerative chambers on the Siemens principle being very advantageous. The development in this country of the manufacture of pressed glass is favorably noticed.

The great European glass works were unrepresented at the Chicago exhibition, with the exception of a handsome display of Bohemian ornamental glassware. Notice is taken of the important improvements made of late in Germany in the composition of glass for various scientific purposes, the Jena glass for optical instruments, for thermometers, and for chemical laboratory vessels (resisting ordinary liquid reagents to a remarkable extent); and it is observed that Japan for the first time sent forth glass of her own manufacture.

Clay ware was much better shown than glass at Chicago, and the reporter seems to have felt especial interest in the details of some of the methods by which more or less new results were obtained.

Mention is made of a new porcelain ware introduced at the Royal Porcelain Factory, of Berlin, which is very refractory and becomes, not denser, but more porous in the firing—valuable for removal by filtering of bacteria from water, for porous diaphragms in electrolysis, etc. There is an interesting account of Japanese clay work, including mention of "Kaga" (hard porcelain) figures formed, not in moulds, but by free hand sculptor's modeling. In connection with the chemistry of clay ware, the extensive use in the United States of Weldon mud for coloring terra cotta, and the free addition of precipitated barium carbonate to prevent efflorescence, receive notice.

Under the head of chemical apparatus and appliances, the very handsome displays made by Hereaus, of Hanau, and Johnson and Matthey, of London, of platinum apparatus, the rare platinum metals and their salts, etc., are spoken of with deserved admiration.

Among the smaller and finer products of chemical manufacture the two most interesting novelties noticed were both American ; viz., the oxides and salts of the rare earthy metals, thorium, zirconium, yttrium, lanthanum, etc., prepared from North Carolina monazite, zircon, etc., and used by the Welsbach Incandescent Gas Light Company, in regard to which it is noted that the higher temperature afforded by "natural gas" gives a better light from the wicks made by skeletons of these metallic oxides than when artificial "water gas" is used, and the new carbide of silicon, or "carborundum," made by Acheson, of Pennsylvania, from sand, coke and a little common salt intensely heated in an electric furnace.

As to the value as an abrasive of this material the reporter states, on the authority of Dr. A. Miethe, that its effect on glass is nine times that of the best emery.

Mixed with 30 per cent of refractory clay, carborundum is moulded into cutting and polishing wheels, and burned in a small porcelain kiln. There is a rather comical notice of the wonder with which were regarded the light color and inalterability of sticks of phosphorus exhibited by J. J. Allen's Sons, of Philadelphia, explained by the fact that for safety's sake the sticks exhibited were made of paraffine.

The brief mention of bromine from Pomeroy, Ohio, and of California borax, does not seem to indicate adequate appreciation of the capabilities for production of the regions in question. It is remarked, and certainly with entire justice, that by far the most extensive and complete exhibition of chemical preparations was that made by Germany ; in fact, no other country made anything like a worthy display. Among the novelties included in the German collection special mention is made of potassium cyanide free from cyanate, made by acting with metallic sodium on the ordinary cyanide, and intended for use in the metallurgical extraction of gold, and notice is also taken of piperazine, so highly recommended of late as a solvent for uric acid.

The reporter found at Chicago little that was new or worthy of special mention in connection with dyeing or calico printing. He mentions with interest some Japanese ornamental work on silk, in which the effect was produced by a combination of printing and free hand painting. This union of block and brush work is of great antiquity (upon cotton) in India. There was but a poor display of textile materials ; it is observed as particularly disappointing that so insignificant an exhibit of raw cotton should have been made by the greatest cotton producing country of the world.

The comparatively small use of candles in the United

States is remarked, and the absence at the exhibition of much that was new in the manufacture of candles and soap, though there was a good deal of both products to be seen, especially of the latter. Favorable mention is made of the excellent glycerine made by Jas. S. Kirk & Company, of Chicago, from the underlye of salted-out soap, by evaporating, crystallizing out most of the salt (to be used over again), precipitating the last remains of the fatty acids in the form of insoluble salts of calcium and aluminum, and distilling the glycerine under much reduced pressure.

As a whole the report is interesting, more so than might have been expected from the inadequate and irregular way in which the chemical products of the world's industry were exhibited at Chicago.

Some new things that either have already attained importance, or seem likely to soon become important, are left without notice. Silver refining and copper refining by electrolysis are omitted, perhaps as metallurgical processes, but it is surprising to find no discussion of the attempts being made to decompose common salt and potassium chloride by the electric current, and so to manufacture by more direct methods than those now in use, the caustic alkalies and alkaline carbonates, bleaching powder, chlorate of potash or soda, etc. Nor is there any notice of the production in the electric furnace of calcium carbide to be used in the production of acetylene for carbureting or enriching illuminating gas (this has been going on in North Carolina for a year or two past). In the thoughtful discussion of American chemical industry—present and prospective—it may fairly be said that the greatest omission is that of any notice of the baneful influence in this country of vacillation in legislation on commercial and industrial matters. However people may differ in their views of public policy in respect to such matters, there is no room for doubt that uncertainty is the worst of all public enemies to industrial enterprise, and from this the United States has suffered much in the past, and seems to have little chance of exemption in the future.

J. W. M.

THE CAUSE OF LUMINOSITY IN THE FLAMES OF HYDROCARBON GASES.*

By Prof. VIVIAN B. LEWES.

IN a paper read before the Chemical Society in 1893 I showed that in the inner non-luminous zone of a flame of ordinary illuminating gas the hydrocarbons originally present in the gas, and consisting of ethylene, butylene, benzene, methane and ethane, became converted, by the baking action of the walls of flame between which they had to pass, into acetylene, and that at the moment when luminosity commenced over 80 per cent. of the total unsaturated hydrocarbons present consisted of this compound.

The presence of acetylene at the point where luminosity commenced naturally suggested that the luminosity was in some way due to actions in which the acetylene played the principal part—either that it split up into carbon and hydrogen under the influence of heat, and so supplied the flame with the solid particles necessary according to Sir Humphry Davy's theory of the cause of luminosity, or else by its polymerization it formed the dense vapors required by Dr. E. Frankland's more recent hypothesis.

The Solid-particle Theory Upheld.—In order to elucidate this point, I carried out the long series of experiments upon the action of heat upon flowing ethylene and other hydrocarbons which formed the subject of communications to the Royal Society in 1893 and early this year, in which I showed that, while flowing through a heated area (the temperature of which was between 800° and 1,000° C.), ethylene decomposed according to the equation—

$$3C_2H_4 = 2C_2H_2 + 2CH_4,$$
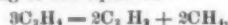
and that the acetylene then polymerized into a large number of more complex hydrocarbons, among which benzene and naphthaline were conspicuous, while at temperatures above 1,200° C. no polymerization took place, but the acetylene formed from the ethylene decomposed at once into carbon and hydrogen, while the methane, which up to this temperature had been but little affected, decomposed into—

$$2CH_4 = C_2H_2 + H_3,$$

and this fresh supply of acetylene at once broke up into carbon and hydrogen ; so that at temperatures above 1,390° C. the complete action might be looked upon as being—

$$C_2H_4 = C_2 + 2H_2.$$

These results have an important bearing upon the cause of the luminosity in the flame, as it is manifest that if the temperature of the luminous zone is above 1,200° C., the light emitted must be due to incandescent particles of carbon, and not to incandescent hydrocarbon vapors.

On determining the temperature of an ethylene flame, while burning from a small fish-tail burner, by means of the Le Chatelier thermo-couple, used in the way described in my paper on the luminosity of coal gas flames (Chem. Soc. Journal, 1893), I found that the temperatures were as follows:

Portion of Flame.	Height above Burner.	Temperature.
Non-luminous zone......	½ inch.	952° C.
Commencement of luminosity....... ...	1¼ "	1,340 "
Top of luminous zone...	2 "	1,865 "
Sides of luminous zone..	— "	1,875 "

Showing that luminosity commenced at 1,340° C. and continued even at 1,875° C., temperatures at which the incandescent vapor theory becomes untenable.

It might be urged that the heavy hydrocarbons already produced at a lower temperature in the non-luminous zone are not so easily decomposed by heat as acetylene, and that these may be causing the luminosity, even though carbon particles be present from the decomposed acetylene ; but this would hardly be possible, as so little besides acetylene is to be found at the top of the non-luminous zone of an ethylene flame, and it can be experimentally shown that even when benzene vapor is formed and is largely diluted it begins to break up and deposit carbon at 1,300° C.

* Communicated to the Royal Society.

The supporters of the solid-particle theory of luminosity agree in concluding that the liberated carbon, existing as it does in a condition of molecular division, is heated to incandescence partly by its own combustion and partly by the combustion of the hydrogen and carbon monoxide going on around the finely divided carbon particles. As has been pointed out by many observers, it is clear that the carbon particles themselves undergo combustion—otherwise they would escape unburned from the flame—while it is manifest that the combustion of hydrogen and carbon monoxide, which plays so important a part in the flame, must add its iota to the temperature attained by them.

Both these sources of temperature, however, would be manifest in the flame itself, and with flames of given size burning from the same description of jet we ought to find that their luminosity is governed by—

A. The temperature of the flame.

B. The number of carbon particles in a given area. Moreover, we should expect that the higher the temperature of the flame, the whiter would be the light emitted ; so that a comparatively low temperature flame, even when rich in carbon particles, would be yellow and lurid as compared with the flame containing the same or a smaller number of particles, but which had a higher temperature.

Temperatures and Illuminating Values Opposed.—It has been pointed out by Professor A. Smithells that it is erroneous to consider the temperature of a flame as being the temperature recorded by thermometric instruments inserted into the flame, as by such devices you only obtain the mean temperature of a considerable area of the flame uncorrected for loss from conduction. (Phil. Mag., 1894.) It is also perfectly well known that in a flame a thick platinum wire may only be heated to redness, while a thin wire may even be fused ; and this suggests that flame temperatures taken by the Le Chatelier thermo-couple of platinum and platinum-rhodium wires may be totally incorrect. In using this beautiful and convenient device, I have found that the length of the wires twisted together makes practically no difference in the recorded temperature, and that one twist is as good as six.

In all my flame experiments I have made the twist as short as possible ; and by always using wires of the same thickness have obtained results which are, at any rate, comparable, if not correct. In order to find what difference the thickness of the wires would make I got Messrs. Johnson and Matthey to draw for me wires of 0·018, 0·011 and 0·008 of an inch diameter ; and having calibrated the galvanometer scale for temperature with thermo-couples of the same length of twist made from each of them, I obtained the following results with the same portion of a Bunsen flame :

Wire Used.	Temperature.
0·018.................	1,617° C.
0·011	1,738 "
0·008	1,865 "

These results show that the diameter of the wire seriously affects the temperature recorded under these conditions by the thermo-couple, the same degree of heat being recorded by the fine wire as being 248° hotter than is shown by the thickest wire employed. This discrepancy is probably chiefly due to loss by conduction.

In taking the temperature of heated gas flowing through a tube, this source of error is but small, as, some considerable length of wire being heated on each side of the twist, conduction has but little effect on the thermo-couple itself ; but in determining the temperature of flames it is manifest that the finest usable wire must be employed, in order to reduce the error from conduction. Text experiments also showed that no part of the thermo-couple must project beyond the flame ; if it did, a considerable diminution in the recorded temperature took place.

For these reasons it was manifestly best to use the finest wire which could be employed without the risk of fusing at the temperatures existing in the flames to be tested. All temperatures recorded in this paper were made with wire 0·011 inch in diameter, the twist being as short as possible ; so that it is probable, although the temperatures may be from 100° to 200° too low, that the results are strictly comparable.

Experiments which I have lately made with pure acetylene, prepared by the action of water upon calcic carbide, show it to be the most powerful illuminant to be found among the gaseous hydrocarbons, as when burned in a small flat flame burner under the most suitable pressure, and its illuminating power calculated to a flow of 5 cubic feet an hour, its value is equal to about 240 candles. The color of the flame is pure white—an ethylene flame beside it looks yellow and dull. The purity of the light at once suggests a very high condition of incandescence in the particles of carbon present in the flame. On taking the temperatures of the various portions of the flame and comparing these with the temperatures obtained in the same way with the ethylene flame and a coal gas flame of the same size, the following results are obtained :

Portion of Flame.	Acetylene.	Ethylene.	Coal Gas.
Non - luminous zone.........	459° C.	952° C.	1,023° C.
Commencement of luminosity..	1,411 "	1,340 "	1,658 "
Near top of luminous zone.	1,517 "	1,865 "	2,116 "

The illuminating values of the gases, calculated to a flow of 5 cubic feet an hour in the burners best suited for their consumption, are :

Acetylene..	240·0
Ethylene..	68·5
Coal gas....	16·3

If all were compared when burning from flat flame burners of the same size as those in which the temperatures were determined, the results, when calculated to a consumption of 5 cubic feet an hour, would be :

Acetylene.....	211·0
Ethylene....	31·5
Coal gas.........	nil.

Here, then, we have the anomaly of three gases which not only do not conform to the preconceived expectation, but which have their ratio of tempera-

ture and illuminating value directly opposed to each other.

In the cases of the acetylene and ethylene, moreover, the molecules contain the same number of atoms of carbon, and yet we obtain so enormous a discrepancy in their illuminating value.

The fact that there is no apparent relation existing between the temperature of the flame, or the probable number of carbon particles contained in it, and its illuminating value, at once suggests that the luminosity must be, in great part, governed by some thermo-chemical changes taking place in the flame itself, and which do not, of necessity, affect the average temperature of the flame to any great degree.

The researches of Hittorf (Wied. Ann., vol. vii) and Siemens, showing the air, steam, and the oxides of carbon, even when heated to temperatures above those existing in luminous hydrocarbon flames, are perfectly non-luminous, and the fact that the Bunsen flame, when supplied with sufficient air, has a temperature exceeding 1,800° C. in its hottest part, and yet it emits no light, show us that it is exceedingly unlikely that any interactions leading to luminosity take place among these ordinary flame gases.

Acetylene Solves the Problem.—The fact that most of the unsaturated hydrocarbons in the flame are converted into acetylene before luminosity commences naturally draws one's attention to this body, and the fact that it is highly endothermic at once suggests the idea that it may be the liberation of heat during its decomposition that endows the carbon particles produced from it with an incandescence far higher than any which could be expected from the temperature of the flame.

Berthelot has calculated that the temperature developed by the detonation of acetylene at constant volume is no less than 6,220° C.; and if this be imparted at the moment of its liberation to the products of its decomposition, the incandescence of the carbon particles is at once explained. If luminosity be even partly due to this cause, the detonation of pure acetylene, first recorded by Berthelot, should develop light. In order to see if this were so, a thin glass tube, closed by a cork, had a detonator containing one-tenth of a gramme of mercuric fulminate suspended in it by two copper wires, which were connected by a thin platinum wire in contact with the fulminate; on firing the detonator by the electric current the flash of the fulminate was found to emit but a feeble light.

The same charge was fired in a similar tube filled with pure acetylene collected over mercury, the result being a flash of intense white light and the shattering of the tube, the pieces of which were thickly coated with the carbon produced by the decomposition of the acetylene. Moreover, the small piece of white tissue paper used to contain the fulminate was only scorched at the points where the explosion of the fulminate had burst through it, showing that in the instantaneous decomposition which had taken place the intense heat which had been developed either was confined to the products of decomposition or else had not had time to scorch the paper.

The experiment at first sight seemed conclusive evidence that it was the endothermic nature of the acetylene which, during its decomposition in the flame, endowed the particles of carbon with the necessary incandescence, but the objection presented itself that when exploding mixtures of oxygen and hydrogen in the eudiometer a distinctly luminous flash is produced. Although the light so obtained is feeble, as compared with the intensity of the white light produced by the detonation of the acetylene, still further proof is necessary before this action can be accepted as the prime factor in producing luminosity.

It is also manifest that it would not do to assume that the rapidity of the decomposition of the acetylene in a flame is nearly so great as when the undiluted gas is detonated, and the question arose as to whether it would be possible to obtain evidence as to acetylene, when exposed to heat alone, liberating carbon in a luminous condition.

Although the instantaneous liberation of heat on the decomposition of the gas by the detonation appears to confine the temperature to the products of its decomposition, it was to be expected that, on being decomposed by heat, and probably, therefore, at a slower rate, the increase in temperature might be detected. To try this, pure acetylene was passed through a platinum tube 2 mm. in diameter and 40 cm. long, in which the Le Chatelier thermo-couple was arranged as follows: The two wires are twisted together for a length of 3 mm., and the wires on either side of the twist are then passed through thin glass tubes, which are fused on them. Having been in this way coated with glass, so that only the twist is exposed, they are passed through the platinum tube, the glass insulating the wire from the metal of the tube and also keeping the thermo-junction in such a position that it registers the temperature of the gas in the tube, not that of the wall of the tube. To each end of the platinum tube glass T-pieces are fitted, down the stems of which the wires pass to mercury seals; from the metal seals, conducting wires lead to the resistance coils, the key, and a reflecting galvanometer.

A steady flow of acetylene was allowed to pass through the tube, and was led into the water at the other end. The tube was slowly and carefully heated for about 4 inches of its length. As the temperature reached 700° C., white vapors began to flow from the tube, and these, as the temperature rose, increased in quantity. The source of heat was so regulated that the temperature rose about 10° per minute, but almost immediately 800° C. was passed the galvanometer registered a sudden leap up in temperature to about 1,000° C., while finely divided carbon poured from the tube. This seemed to indicate that 800° was about the temperature at which pure acetylene broke up into its constituents.

An experiment was now made to see if this developed incandescence in the liberated carbon. A small glass combustion tube was well supported, and heated to the highest temperature attainable with one of Fletcher's big blowpipes, while pure acetylene was slowly flowing through it, the heating not being commenced until the tube was filled with pure gas, all air being thoroughly rinsed out. As the temperature reached the softening point of the glass, the acetylene apparently burst into a lurid flame at the point where it entered the zone of heat, and clouds of carbon

swept forward through the tube; but, although the carbon particles had to traverse an inch or more of tube more highly heated than the point of entering the hot zone, it was only at this latter point that the luminosity was developed, proving beyond doubt that it was the heat evolved by the decomposition, and not the external heating, which caused the carbon particles to emit light.

(To be continued.)

ACETYLENE.

A PAPER on this new illuminating agent was recently read, in Berlin, by Herr M. Hempel, of that city. It is printed in extenso in the Journal fur Gasbeleuchtung, whence the following summary of its contents is made by the Journal of Gas Lighting.

The constituents of coal gas are arranged into three groups, according to their value as illuminants or diluents, or their presence in the gas as undesirable as purities. Acetylene exists in coal gas, though scarcely to the extent of 0·1 per cent., and it ranks high in the class of illuminants. It has a specific gravity of 0·91, and burns with a very bright but smoky flame.

Only since the discovery by Willson of a method of producing it in a state of purity, on a large scale, has it advanced to the position of a practical illuminating agent. Calcium carbide is a compound of carbon and calcium which may be made in various ways. For instance, it is formed by strongly heating an alloy of zinc and calcium in contact with coal, or by the action of a powerful electric current on a mixture of lime or chalk and coal. It has a specific gravity of 2·262; is bluish or golden-brown in color, and of metallic luster; and, in odor, it resembles garlic. Acetylene is evolved when calcium carbide is brought into contact with water. There is no known solvent of calcium carbide; it is unacted on by hydrogen and nitrogen at all temperatures; at 245° C., chlorine forms with it calcium chloride and carbon; at 500° C., sulphur vapor acts on it to form calcium sulphide and carbon disulphide; arsenic and antimony are the only metals that attack it; and, in a stream of oxygen, it glows faintly, and calcium carbonate is formed. Steam is far less active than water toward it.

Practically, calcium carbide is now formed in the electric furnace from tolerably pure lime and coal. Acetylene is formed by merely allowing water to rise gradually in a vessel in which the carbide is exposed on grids. The gas needs no purification, and it is at once conveyed to the holder. Any sulphur in the coal used for the manufacture of the carbide is retained in the form of calcium sulphide with the residual lime. It is evident that the apparatus needed for the production of acetylene is very limited and simple. Owing to its high density, acetylene must be supplied to the burner at about double the pressure at which coal gas is ordinarily burnt.

Acetylene is liquid under considerable pressure. At 0° C., the liquid has a vapor tension of 21·5 atmospheres, and at 31° C. (88° Fah.), 103 atmospheres. It is poisonous, but the smallest quantities are easily detected in air on account of its penetrating odor.

The following are some of the results of comparative tests of illuminating power and consumption of coal gas and acetylene in various burners. (The values are given in the original terms—i. e., of the German candle—and should be multiplied by 1·05 to give approximately the values in English standard candles.)

CONSUMPTION AND ILLUMINATING POWER WITH VARIOUS BURNERS.

Gas Used.	Burner.	Consumption per Hour.	Illuminating Power.	Candles per Cubic Foot.
		Cubic Feet.	Candles.	
Coal gas	Hollow top	5·3	13	2·45
"	Argand (ordinary)	5·65	16	2·83
"	Siemens No. 4	7·05	33	4·68
"	" No. 2	21·2	130	6·13
"	" No. 00	84·75	650	7·67
	New Welsbach	4·24	45	10·61
Acetylene	Batswing No. 1	1·235	45	36·44
"	" No. 3	2·37	97	40·93
"	" No. 5	3·25	143	44·00

Like other heavy hydrocarbons and oil gas, acetylene needs a very powerful air supply in order to burn with a clear white flame. An external air supply is insufficient for its proper combustion in plain batswing burners; and, for the above trials, air was mixed with it in regulated proportion in the burner. The best results were obtained with two volumes of air to three volumes of acetylene. In special burners, however, acetylene may be burnt without previous admixture with air. Thus in an English rat tail burner, it gave an illuminating power of 38 candles for an hourly consumption of 0·7 cubic foot. A consumption of 5 cubic feet an hour in a German-made Argand gave a value of 240 candles, or a duty of 48 candles per cubic foot of acetylene. The lighting value of acetylene is in this case nearly twenty times that of coal gas in a hollow top burner, or 4·5 times that of the same gas in the Welsbach burner.

Notwithstanding its greater brilliancy, the acetylene flame is far cooler than that of coal gas in a similar burner—partly on account of the lower proportion of hydrogen in acetylene and partly on account of the lower rate of consumption. From calorimetric experiments by Dr. Bueb, of Dessau, acetylene appears to have a heating value of 407 calories per cubic foot; but the author, on theoretical grounds, reckons it should be about seven-eighths of this value. Light for light, the products of combustion are very much less from acetylene than from coal gas.

From Dr. Poleck's analyses of Breslau coal gas, it would appear that it produces on combustion 1·8 times its volume of aqueous vapor and 0·6 time its volume of carbonic acid. The corresponding figures for acetylene are one volume of aqueous vapor and two volumes of carbonic acid. For the production of 100 candles per hour in the Welsbach burner, 9·4 cubic feet of coal gas are required, furnishing on combustion 12·2 cubic feet of aqueous vapor and 5·64 cubic feet of carbonic acid. The same lighting value is obtained from, on an average, 2·119 cubic feet of acetylene, producing its own volume of aqueous vapor and 4·238 cubic feet of carbonic acid on combustion.

Acetylene consumes a less quantity of air than coal gas in the production of a given amount of light. The coal gas needed for 100 candle hours in the Welsbach burner requires about 56·5 cubic feet of air for its combustion; whereas the volume of acetylene that yields the same light requires only 26·5 cubic feet of air.

The acetylene flame emits pure white light, and therefore shows objects in their natural colors; and it is also valuable to photographers. The maximum explosive force is obtained from acetylene when it is mixed with twelve times its volume of air. Coal gas requires only six times and water gas only once its volume of air for explosion.

Acetylene should provide a very practicable means of enriching coal gas. The following figures for its enriching power are taken from a diagram issued with the paper.

MIXTURE OF ACETYLENE AND COAL GAS.

Percentage of Acetylene in Mixture.		Illuminating Power in Candles.
0	about	10
10	"	12
16	"	38
30	"	58
64	"	101
70	"	126
73	"	171
100	"	240

The high density of acetylene would lead to stratification were it introduced into coal gas in the holder. It is therefore proposed to affix an apparatus for the production of acetylene to the outlet of each consumer's meter, and to supply a poor gas, which can be enriched by acetylene when it is needed for lighting purposes. A cheap gas would by this means be available for heating and driving engines. On the other hand, portable lamps containing sufficient carbide to produce acetylene for several hours' consumption can readily be constructed.

ON THE PROPERTIES OF AMORPHOUS SILICON.

By M. VIGOUROUX.

IN a former paper we have indicated that it is possible, under certain conditions, to reduce silicon by magnesium, and to obtain an amorphous silicon quite free from foreign bodies. The properties of this substance are as follows:

PHYSICAL PROPERTIES.

It is a fine powder of a maroon color, and adheres to any moist or rough surface. It readily absorbs gases and watery vapor, and requires for their expulsion to be heated to near redness. Its mean specific gravity at 15 degrees is 2·35. It may be melted and easily volatilized in the electric furnace. It is soluble in a great number of metals in a state of fusion.

CHEMICAL PROPERTIES.

It does not seem to be affected by heat. It has been practicable to raise it for a long time to high temperatures without any alteration in its properties, which depends on the strong heat liberated at the moment of its preparation. Hydrogen has no action. Fluorine attacks it at common temperatures.

In chlorine silicon ignites at 450 degrees, and in bromine about 500 degrees; in iodine there is neither incandescence nor apparent reaction.

In the oxygen of the air there is superficial oxidation without incandescence. In pure oxygen there is brisk combustion about 400 degrees, and the heat is such that the silicon formed is melted.

In sulphur, incandescence occurs about 600 degrees. In nitrogen it does not react below 1,000 degrees; at a higher temperature it attacks. In silicon it forms an amorphous nitride. Phosphorus, arsenic and antimony, if heated with it, distill without reactions. Carbon and boron act only in the electrical furnace. The metals seem not to combine with silicon at temperatures generally available in laboratories. Magnesium alone yields a silicide with lively incandescence.

Dry gaseous hydracids attack it slowly about dull redness. Hydrogen sulphide, if gradually heated up to its dissociation point, does not act upon the silicon. Ammonia is decomposed at cherry redness; hydrogen is liberated and the nitrogen combines with the silicon, forming a nitride.

Watery vapor is decomposed at the same temperature, forming silica and hydrogen, which escape. The decomposition is continuous, but slow. Sulphurous anhydride, if passed over silicon at about 1,000 degrees, is not reduced. Nitrous and nitric acid act slowly toward 800 degrees, with fixation of nitrogen and oxygen. If the reaction is lively, there is incandescence. Phosphoric anhydride is reduced with incandescence before a red heat. It is the same with the oxygen compounds of arsenic and antimony. Between 800 degrees and 1,000 degrees carbonic anhydride is reduced to the state of carbon monoxide. The latter is not attacked even at 1,200 degrees. Silicon is not attacked by any acid dissolved, or liquid, if acting alone, nor by fuming nitric acid heated to ebullition, nor by sulphuric acid concentrated and boiling, nor by concentrated hydrofluoric acid if heated with it to 100 degrees. The combined action of two acids, or of an acid and another body, is often effective. Thus aqua regia at 100 degrees acts in course of time, and ultimately transforms it into anhydrous silica. A mixture of nitric acid and hydrofluoric acid attacks it at the common temperature, with an escape of muddy fumes and of silicon fluoride. Hydrofluoric acid, mixed with potassium nitrate or chlorate, acts with violence; it is the same with ordinary nitric acid if mixed with potassium fluoride.

Silver fluoride is decomposed with incandescence before a red heat; there are formed silicon fluoride and silver, which is set at liberty, and is found in small melted grains. It is the same with zinc and lead fluorides, etc.

Most oxides are reduced in glass tubes heated with a Bunsen burner, in many cases with incandescence; such are mercury, copper, lead, bismuth, tin, iron, manganese oxides, etc. The alkaline and alkaline earthy oxides are attacked energetically.

Hydrofluoride of potassium fluoride seizes the silicon

and liberates hydrogen. Lead sulphate and calcium phosphate are reduced. The silicon may be thrown upon potassium chlorate in decomposition without incandescence, but this phenomenon occurs if the two substances are intimately mixed and then heated. Potassium nitrate reacts only at its decomposition temperature. The alkaline carbonates, whether in solution or fusion, convert it into silica. Certain oxidizing agents, such as potassium dichromate and lead chromate, are decomposed with incandescence and explosion below a red heat. The mixture of fuming nitric acid and potassium chlorate has no appreciable action.

The amorphous silicon obtained by reducing silica with magnesium corresponds neither to the amphorphous varieties α or β of Berzelius. It approximates rather to crystalline silicon. Nevertheless, the latter has hitherto been regarded as incombustible in oxygen.

This indifference is only apparent. If we raise the temperature abruptly the crystalline silicon ignites at 400 degrees in oxygen, and burns with a dazzling luster. If it is finely powdered, the combustion may be complete.—Comptes Rendus, cxx., p. 367.

THE SAN JOSE SCALE.*

(Aspidiotus perniciosus Comstock.)

By Prof. C. V. RILEY.

No insect is just now of more importance to the fruit growers of Maryland than that which has been designated by the above popular name, given to it because it first became known or was first particularly noticed around San Jose, California. It is exceptionally injurious, usually causing the death of the affected trees; occurs on a great variety of deciduous trees, and has great power of multiplication. It was only in the autumn of 1893 that the presence of this insect, which is one of the worst with which California fruit growers have had to deal, was suspected on the Atlantic coast. It was then thought to be restricted in its range, and I had hopes that it might be effectually stamped out. But during the past year it has been found at or reported from so many new localities in the East, all the way from Florida to New Jersey, including the States of Maryland and Virginia,
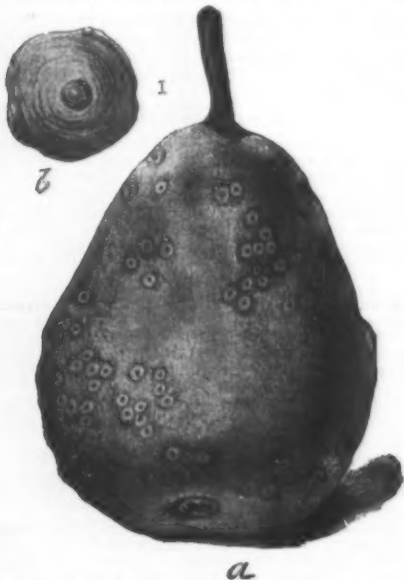
FIG. 1.—San Jose Scale—a, pear, moderately infested, natural size ; b, female scale, enlarged. (From Insect Life.)

that there is no hope of being able to exterminate it. It has come to stay; but, as it is possible to very materially limit its injury and spread, and by proper precautions to prevent its introduction into districts in which it does not yet occur, I feel warranted in giving a pretty full account of the species in the present bulletin.

ITS HISTORY IN THE ATLANTIC STATES.

Early in August, 1893, specimens of this species were first brought to my attention, while yet government entomologist, by Prof. B. T. Galloway, Chief of the Division of Vegetable Pathology, United States Department of Agriculture, who received it on a pear sent by Dr. C. H. Hedges, of Charlottesville, Va., who had mistaken it for a fungus disease. On the supposition that it might be restricted to Dr. Hedges' trees, I took active steps to furnish all possible information about the subject, and endeavored to interest the State Board of Agriculture of Virginia. I had the infested region at Charlottesville carefully investigated by Mr. E. A. Schwarz and Mr. D. W. Coquillett, whose reports were published in "Insect Life," vol. 6, pp. 247 and 253. The insect was found on pear, peach, plum, apple, quince, rose, currant, gooseberry, and raspberry. The careful survey of the field thus made seemed to justify the belief that this was a local and restricted outbreak. I called attention to this outbreak at the Madison (Wis.) meeting of the A. A. A. S. in August, 1893, and later at a meeting of the State Board of Agriculture at Newport, Va., read a paper upon the subject, urging active measures for the insect's extermination, and pledging, on Secretary Morton's account, the active co-operation of the national department in such measures.

Believing that the most effective way to exterminate was by the use of what is known as the gas treatment, i. e., the fumigation of the trees under a tent by means of hydrocyanic acid gas, this being known as the most effective insecticide and most likely to reach and kill all the insects, my first efforts were in this direction. It was the first time that efforts had been made to em-

*Abstracted from advance copy of Bulletin No. 23, Maryland Agricultural Experiment Station.

ploy the gas treatment in the Eastern States on deciduous trees, though it has been used for many years and is very popular in the orange groves of California. Mr. Coquillett, who had acted for many years as agent at Los Angeles under my direction and who had discovered and developed this gas treatment, was fortunately with me in Washington at the time, so that the treatment was intrusted to him. We had some difficulty, in the first place, in getting the tents manufactured, and still further difficulty in putting them in operation. There are various contrivances in California used for the operation of these tents, the simplest of which,

FIG. 2.—San Jose Scale—Apple branch, with scales in situ ; natural size. (From Insect Life.)

perhaps, for average sized or small trees, are poles with which the two ends of a quadrangular tent are thrown over the tree, the tree itself supporting the sheet. In the Charlottesville case the tents were constructed of 8 oz. duck and made in the form of an octagonal sheet, and were oiled with boiled linseed oil, two of them measuring 28 and the other two 44 feet in diameter. The fumigation was subsequently reported to have been successful in destroying the insect without injuring the trees, though some of these had already begun to leaf out or were in blossom. Later examinations, however, showed that a few of the insects had escaped death, and this was in keeping with experience subsequently had with the gas treatment in Montserrat, and which showed that, where the scales are thick, some of the eggs survive a single fumigation.

During the period when the experiments were being made, or during March and April, 1894, fate had decreed that I should be absent in the West Indies. After making all due arrangements to have the work of extermination thoroughly prosecuted, and after having finished my annual report, which included an illustrated article upon this San Jose scale, I suddenly decided to make a trip to the West Indies, more particularly to study two scale insects, viz., the purple scale (Mytilaspis citricola) and the orange scale (Chionaspis citri) which, under the denomination of "blights," had been for some years killing out, not only acres but square miles of limes on the island of Montserrat. This trip was taken at the earnest solicitation of the Montserrat Company, of Birmingham, England, without any cost to the Department of Agriculture and without any remuneration to myself. The importance of the matter and the indirect bearing of the results on the management of these two scales, which also affect citrus trees in Florida, justified my request for leave of absence for this purpose. Very thorough fumigation was being carried on there by an expert, Mr. R. T. Mullard, from Los Angeles, as the washes usually effective with us, seemed less so there. The condition of things was most interesting and exceptional, and I felt that a study of it might prove valuable, not alone to the Montserrat people but to our own.

It was during this absence from the department that specimens of the San Jose scale were brought to Mr. L. O. Howard, my assistant in charge, from Riverside, Charles County, Maryland. He at once had the matter investigated. Some 20 acres are planted to an orchard which contains some 2,000 peach trees, having some 250 apple trees mixed with them. The introduction could be traced to the planting in the spring of 1888 from stock obtained from the old established and
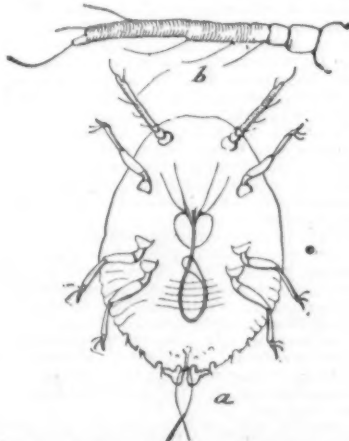

FIG. 3.—San Jose Scale—a, young larva, greatly enlarged ; b, antenna of same, still more enlarged. (From Insect Life.)

well known nurseries of Wm. Parry, at Parryville, N. J. Many of the older trees were found to be dead, and most of the others badly affected. Adjacent orchards within a radius of two miles, the stock of which had been obtained from other nurseries, were found to be quite free from the scale.

Later in March further specimens were received at the department from De Funiak Springs, Fla. Here the insect, as subsequent evidence showed, was found not only upon peach and pear, but also upon pecan and persimmon. Mr. Howard, as acting entomologist, now deemed the matter of sufficient importance to issue a circular of warning. This gave a summary of the information at hand with certain figures that I had ordered prepared for an intended article in Insect Life. The circular was widely distributed both directly to Eastern fruit growers and through the news-
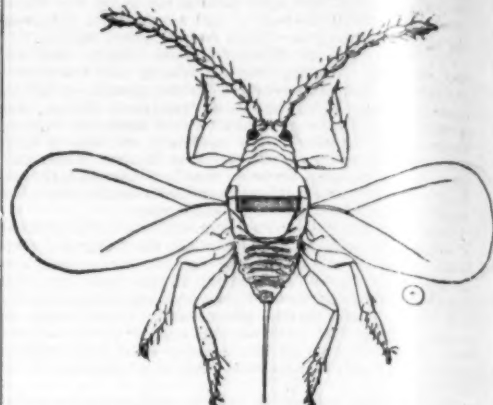

FIG. 4.—San Jose Scale—Male adult, greatly enlarged. (From Insect Life.)

papers, and, as a result, a number of new localities of infection were discovered, and among them Neavitt, Talbot County, Md. The infested orchard is located on one of the inlets of the Chesapeake Bay and contains about fourteen acres of peach trees, and all of the trees were found to be badly affected. So far as investigation could determine, both by Mr. Coquillett and Mr. Howard, the first trees planted in this orchard were received from Stark Brothers, of Louisiana, Mo.

Later, Mr. Marlatt discovered another infested locality in Maryland, on the place of Capt. R. S. Emory, at Chestertown, in Kent County, and the original trees were here also traced to the New Jersey nursery afore mentioned.

The insect formed the subject of two important papers at the sixth annual meeting of the Association of Economic Entomologists in Brooklyn the following August. One of these was by Mr. Howard, giving a full account of the work done by the Department of Agriculture and its results, and the other by Prof. J. B. Smith, of the agricultural experiment station of New Jersey. As a result of the discussion at that meeting the occurrence of the insect was subsequently established in parts of Columbia County, N. Y., lying on the east bank of the Hudson River, below Albany, and in several localities on Long Island.

Still later in the season, as shown by some further notes of the subject, by Mr. Howard, still further localities for the insect were discovered, viz.: Southern part of Georgia, Clearmont County, Ohio, Newcastle County, Delaware, City Point, Prince George's County, Virginia, and at Bristol, Pennsylvania, while three other localities were added to Maryland ; one in Prince George's County, one in Anne Arundel County and one in Washington County.

There can be no question but that future investigation will show that the insect is quite widely disseminated in many other localities not yet discovered, not only in orchards and nurseries, but also in isolated grounds, and that this general statement will apply to Maryland as well as to the other States in which it has obtained a foothold, and, while the energetic efforts that have already been made to stamp it out will go so far toward doing so, we must accept the situation and acknowledge that the species has come to stay. While, therefore, I consider that its entire extermination from so many points of infection over so large an area is impracticable and not to be hoped for, yet there is no reason why its spread to other localities may not be very materially if not entirely checked. This, however, can only be done by intelligent action, not only
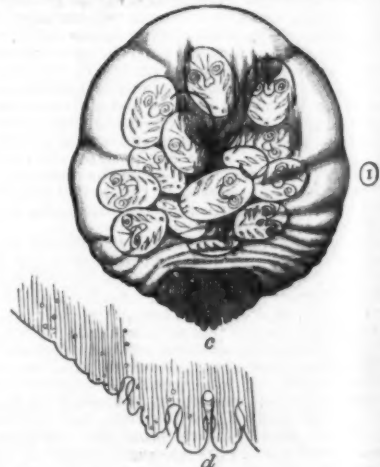

FIG. 5.—San Jose Scale—c, adult female containing young, greatly enlarged ; d, anal fringe of same, still more enlarged. (From Insect Life.)

on the part of individuals, but by systematic and concerted action of communities made obligatory, if need be, by proper legislation.

LIFE HISTORY OF THE SPECIES.

In order not to repeat too much in detail the phases

of development common to this and other species of scale insects which belong to the same sub-family, viz., the Diaspinae, or armored scales, it may be well, in this connection, to state a few characteristics which belong to almost all of them. This sub-family includes many of our worst scale insects, like the red scale of the orange in California (Aspidiotus aurantii), the scurvy scale of the apple (Chionaspis furfurus), the oyster shell bark louse of the apple (Mytilaspis pomorum) and many others. The young or newly hatched individuals are almost microscopic creatures of white or pale yellow color, with body of ovoid form, flattened, with six legs, two short feelers having a varying number of joints, but rarely more than eight, and with two filamentous hairs at the end of the body. They are active but a brief period, sometimes but a few hours or even minutes, rarely more than a day or two, and settle upon the bark near where they are born if there is a chance and it is not already too thickly covered with the parent scales. A long thread-like proboscis is gradually thrust under the epidermis and the insect becomes fixed and a flocculent waxy secretion begins to cover it. This increases until the larva underneath molts. The first larval skin becomes part of the secretion or shield, and is known as the larval scale, and the insect under it after this first molt loses its legs and feelers. The covering still further increases, and a second molt takes place, and we have a scale which is known as the medial scale, and which surrounds or extends from one end of the larval scale, according to the species. In the male the form of this scale is usually very much narrower than in the female, and often ribbed; it is, also, often markedly of a different color, or pure white, while the female scale is usually darker, or imitates the color of the bark. Thus the sexes are now distinguishable by their scales or shields, while the insects themselves are also readily distinguished at this stage, the male having transformed to a pupa, with the limbs, feelers and wings foreshadowed, and the female remaining a mere yellow mass without such organs.

In the male a third molt takes place under the medial scale, and a delicate two-winged fly with long feelers and a single anal style backs out from the rear end. His color is usually pale, with a reddish or dusky band across the middle of the thorax, and the wings have but two delicate veins. The antennae are variously jointed, the more common number of joints being eight. In the female scale, on the contrary, there is no particular difference of form after the second molt. She still grows and is destined to remain underneath her scale, which becomes much larger and forms what is known as the anal sack. Here, after a third molt, she becomes fertile and either produces her young alive or lays her eggs. In either case the young in due time issue from the scale and begin again the cycle of life, as already related. In those species in which the scale is more or less circular, like the one we are considering, the stages of the scale growth are not so readily separated as in the elongate species which resemble an oyster shell or a mussel shell. The larval scale is, however, usually conspicuous, as a central raised point. The different species of the sub-family are distinguished from each other not only by the peculiarities of their scales, which do not always offer trustworthy separating characters, but by the peculiar arrangement of the secretory pores on a darker and more chitinized anal plate, and by the peculiarities of the margin of this plate, especially in the female.

Our particular San Jose scale is quite circular in form, very flat and pressed close to the bark. It grows from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in diameter in the female and about half this size in the male. It has the general color of the bark and the larval scale in the center is a slightly raised point varying from yellowish to nearly black in color. It is one of our smallest scales and is further characterized and distinguished from all others which the fruit grower has to deal with by producing around the edge a peculiar red or purplish stain which penetrates for some depth in the formative tissues of the bark, and is particularly noticeable when the scales are sparse and not too crowded, or when upon fruit of an ordinary pale color. Another peculiarity is the relatively large size and bright yellow color of the newly hatched young. At a short distance, when a branch or a tree is badly affected and the scales overlap each other, the tree looks as though it had been covered with lime or ashes, and when crushed or pressed or scraped the mature insects beneath the scales, if alive or fresh, produce a yellowish and rather greasy liquid.

The accompanying figures, with the explanations underneath, show very well the appearance of the scales upon a pear (Fig. 1); their general appearance on an apple branch (Fig. 2); a ventral view of the young scale, with a larger view of one of its antennae (Fig. 3); a dorsal view of the male (Fig. 4); and a ventral view of the female (Fig. 5), with her ova developing, and with a large outline of a portion of the anal plate—the last three figures being very highly magnified and the natural size approximately indicated within an accompanying circle. The ordinary fruit grower would hardly be able to separate it from several other common insects which have existed in the Eastern States from time immemorial, were it not for the smaller size and the reddening effect which it produces upon the bark.

The observations made at the Department of Agriculture would indicate that there are no very exact limitations between the various generations or broods of this insect, and that there may be some five annual generations in the latitude of Washington, each generation occupying on the average some 40 days. The females hibernate in various stages of development, but mostly as mature and impregnated individuals, since the male does not hibernate. The species is viviparous, i. e., the young are born alive. This has been made quite clear by the observations in the East and especially at Washington, though some writers have stated that eggs are produced. It is quite probable that both statements may be based on facts, and that there may be variation in this respect according to season, locality or conditions. One thing however is clearly determined, viz., that the species may be viviparous throughout the year.

The large number of generations is exceptional, though there is some compensation in that the individual is less prolific than in those species which produce fewer or but one annual generation. The individuals which have hibernated acquire full development, and begin to produce young by the end of May

or the first of June, and from this time on there is a succession of generations. As in almost all other species of scale insects, the male scales, produced most in summer, are, for the most part, formed on the leaves and show a tendency to gather along the midrib on the upper side.

The matter of most practical importance in the life history of the species is that it continues multiplication from the beginning of June until late in the autumn, or until winter weather has fairly set in, and that during this time there is practically no period when the insect will not occur in almost every condition.

(To be continued.)

THE GREAT AUK.

At the auction rooms of Messrs. Stevens, in King Street, Covent Garden, recently, a number of spectators surveyed a bird sitting or standing there with great admiration and respect. He was a big bird, perhaps of the size of a Michaelmas goose, and he had an expanse of white bosom of a spotlessness which would excite the envy of a German waiter. He had a white splash over each eye, but his head, his webbed feet, and his elegantly shaped back were black as ink. His eye was glassy, and he stood the fire of remarks and comments upon his appearance with an immovable composure, for he was stuffed. He was a great auk, and he was extinct; but neither of these facts affected his bearing, although both affected his price. When he was put up for auction, Mr. Stevens made a little speech about him which was so complimentary that the casual auditor could not restrain the conviction that it was just as well that the bird was too extinct to hear him, for otherwise its head might have been turned.

What was the number of great auks when all the

THE GREAT AUK AND EGG WHICH WERE OFFERED FOR SALE BY AUCTION.

world was young and the plesiosaurus coqueted with the mastodon, nobody can tell. But the number of stuffed great auks now known to civilization, said the auctioneer, was only eighty. This rarity was still more real than apparent, for, of the whole number, sixty were in museums, where they were likely to stay. Indeed, only one great auk had been put up to auction in the last twenty-six years. Twenty-four of these noble birds, pursued Mr. Stevens, were in Great Britain, but of this number ten were in museums, and the slenderness of the chance that any of them would come into the market would be quite obvious to any of his hearers. And what was the value? Well, the last great auk went at the ludicrous price of £90, but at the same sale an egg only fetched £60. Last year an auk's egg was sold in the Covent Garden auction room for 300 gs.; and, therefore, concluded Mr. Stevens, triumphantly, it would be obvious that according to the rule of three the present value of a great auk should be somewhere between £500 and £600.

The audience smiled, and the auctioneer went on to declare his unhesitating belief that this was the finest specimen of a great auk in existence; it was absolutely genuine; it was not made up at all, nor had it a single false feather; and it was the property of Sir Frederick Milner, Bart. The remaining part of the sale can be conveniently cast into the form of a paragraphic monologue on the part of the auctioneer.

"It is," said Mr. Stevens, "a perfect bird, as fresh and as clean as on the day it was hatched. Who'll make a bid for it? I think I am safe in putting it in at 100 guineas. 110. Thank you. 120—130—140—160."

"160: don't stop there, gentlemen: this is very slow. 180—200—220—240—250—265 guineas bid. It would be ridiculous if this bird fetched anything under 500 guineas."

"260 guineas—270—280—300 guineas. Thank you.

This noble bird 300 guineas—310—320—330. Isn't it a wretched price, gentlemen?" The audience sighed sympathetically, but 330 guineas is a lot of money for a bird, and another sigh—this time of relief—went up when another bidder said 340. This bid was followed by 350, and here the bidding stuck. In vain the auctioneer reasoned, pleaded, protested. Nobody would go a shilling better, and so Mr. Stevens had reluctantly to announce that the reserve price had not been reached, and the great auk would be withdrawn. It was a humiliating moment for everybody, but the bird came out of it unruffled. It is believed that he will be disposed of privately.

After this an egg of the great auk, not of this noble bird, but of some two thousand years distant relative, was put up for sale. Mr. Stevens had exhausted much of his powers of eulogy on the bird, but he had sufficient left to declare this to be one of the finest eggs he had ever seen, and greatly superior to the phenomenon which fetched 300 guineas at these auction rooms last year. Those who were present on that celebrated occasion, perhaps, would be unable to recall anything in the auctioneer's speech which would have seemed to indicate that there was any other auk's egg superior to the one he was then putting up in general desirability, and bidders took the same view, for the highest bid that could be obtained was only 180 guineas. At this price it was sold to the proprietor of a public house who keeps a small private museum for the entertainment and instruction of his patrons. After this no one was surprised to find that an egg of the Æpyornis maximus—in size, shape and color very much like a new Rugby football—was sold for thirty-six guineas.—Daily Graphic, London.

THE SPECTROSCOPE IN ASTRONOMY.*

By TAYLOR REED.

Of star spectra there are three main classes: First, spectra with few lines, but some extremely wide lines; second, spectra like that of our own sun; and third, spectra containing bands. The white or bluish-white stars as a rule give spectra of the first class; and as Sirius has a spectrum of this nature, this class of spectra is often called the Sirian type. Yellow stars show spectra of the second class (our sun is probably yellowish). Some few red stars give spectra of the third or banded type. Stars are therefore classified from their spectra as white stars, yellow stars and red stars; or often their spectra are said to be of the Sirian type, of the solar type or banded. The Sirian type includes a little more than half of all the stars; conspicuous are Sirius, Vega, Altair, Rigel, Castor, Spica, Regulus. Stars of the solar type are a little less numerous; among them Capella, Arcturus, Pollux, Aldebaran. Of stars giving banded spectra there are but a few, and all are distinctly red; the brightest are Betelgeuse and a Herculis.

A very few stars have peculiar spectra, which scarcely come under any of the main classes.

In spectra of the Sirian type the metallic lines, of which there are so many in the sun's spectrum, are mostly faint or absent. And the hydrogen lines are usually enormously wide. The hydrogen lines vary both in width and in intensity. In some stars they are extremely wide; in others little wider than in stars of the solar type. In some stars the lines seem densely black; in some noticeably not black; and in two stars, γ Cassiopeiæ and β Lyræ, the hydrogen lines are positively bright. As for the other lines, in some stars scarcely any can be seen; and in some they are not radically less numerous and clear than in the solar type.

Among stars of the solar type are some like Capella, whose spectra seem to be identical with the sun's; others, like Arcturus, give spectra differing noticeably from the sun's, though by the multitude and relative prominence of their lines still plainly of the solar type.

Of spectra with dark bands there are two classes: In most the bands are sharp and dark at the side toward the violet and shade out toward the red; in a very few (all faint) the bands are sharp toward the red. In addition to the bands dark lines appear. The violet end of such spectra is always relatively faint.

Half a hundred faint stars near the Milky Way give spectra containing bright lines or bands as well as dark lines. From the discoverers of the first examples they are usually called the Wolf-Rayet stars.

New stars or temporary stars (such as Nova Aurigæ) usually at their appearance give spectra with the usual number of dark lines, but the hydrogen, helium and a few other lines bright. Within a year or so, for no known reason, the spectrum has changed utterly in character, so as to consist chiefly of one bright line in the green; the new star has become a planetary nebula.

Nebulæ give spectra of two classes. In one the spectrum is continuous, with no lines, bright or dark. In the other there is a very faint continuous spectrum and one very brilliant line in the green, together with a number of very faint bright lines, including lines of hydrogen; these nebulæ are therefore masses of shining gas under low pressure. Of the two great nebulæ, the nebula of Andromeda gives a continuous spectrum, the nebula of Orion a bright line spectrum. The planetary nebulæ give bright line spectra. As to the nature of this principal nebular line there has been dispute; the majority of best observers see it as a line definite and equally sharp at both edges, not the remnant of a fluting. This line is almost certainly due to no known terrestrial substance.

The distribution of stars of different types in the sky is an important point in cosmogony. Stars of the solar type are distributed over the sky with substantial evenness. Stars of the Sirian type are much more numerous in the Milky Way. Are we therefore among solar stars evenly distributed in space, and in the center of a ring or disk of Sirian stars? Further, many solar stars and few Sirian have appreciable proper motions; showing that probably the Sirian stars are farther from us than the solar of equal brightness. Are the Sirian stars then larger than the solar, or brighter?

To deduce the state of a star from its spectrum is probably to guess rather than to reason. But the general belief is that a Sirian star is hotter than a solar and has a greater hydrogen envelope; that in all the

characteristics of a sun a Sirian star is yet more a sun than our sun. And most agree that the temperature of the red stars is not nearly so high.

Much work has been given to determining the motion of a star toward us or from us (that is, "in the line of sight ") from the shifting of the lines in the spectrum toward the blue or toward the red. Such motion in a few stars may be known within a mile a second ; for quite a number of stars, it is probably known within five miles a second. It is found that the velocity of stars with reference to the solar system is not very different from the velocity already assumed for the sun in space.

A fair average is probably 20 to 25 miles a second. Few have velocities over 60 miles a second. In particular the motion of planetary nebulæ in the line of sight has been examined with the greatest spectroscopic power, and their velocities are comparable in amount with stellar velocities. But great as are these velocities they have brought no star to us and carried none from us enough seriously to change its brightness, even since the earliest ages, as a little figuring will show.

Let a star be a close binary, with equal components, so revolving that we are in or near the plane of its orbit. When the line through the two components is directed toward us, neither component is approaching us or receding from us. One-fourth of a revolution later the line through the components is perpendicular to the line from us to the star ; one is then moving toward us in its orbital revolution, the other away from us. At this time the lines in the spectrum due to one component are shifted toward the blue, those due to the other component toward the red, that is, if the orbital motion is great enough, the lines of the star's spectrum are doubled. Now, this periodical doubling, indicating a "spectroscopic binary," has been observed in Spica, β Aurigæ, and Mizar (ζ Ursæ Majoris). The orbital period of such a binary is measured in days, and the two components must be so close that no telescope will ever separate them.

Let the variable star Algol have a smaller dark component which partially eclipses the bright. At eclipse neither is moving toward us nor from us.

One fourth revolution after eclipse the dark body is moving from us, and Algol toward us. One-fourth revolution before eclipse the dark body should move toward us, Algol from us. This motion of Algol from us before eclipse and toward us after eclipse should be seen in the displacement of lines in the spectrum. And this displacement has been detected. The spectroscope so seems to confirm the eclipse theory of stars of the Algol type. From this is derived our first serious estimate of the diameter of a fixed star. Assuming only that we are nearly in the plane of the orbit so that the eclipse is central, the measured velocities give : For the diameter of Algol proper, 1,000,-000 miles ; for the diameter of the dark companion, 800,000 miles ; for the distance between the centers of Algol and companion, 3,200,000 ; orbital velocity of Algol, 25 miles a second ; orbital velocity of companion, 54 miles a second ; mass of Algol, four-ninths that of the sun ; of the component, two-ninths that of the sun. This indicates that in magnitude Algol at least is of the same order as our sun ; and Algol is a Sirian star.

In these articles the attempt has been to state some of the results of spectroscopic work. Such outline must indicate the greatness of spectroscopic phenomena, but not their surpassing beauty. And many of the most beautiful are well within the ability, experimental and financial, of the amateur.

In procuring a telescope, except where special work is selected for it, I think it sound judgment to sacrifice a trifle in size (not in perfection) of the telescope to procure spectroscopic accessories. Any equatorial telescope with clockwork can properly carry a solar spectroscope, and any one who can manage and care for such a telescope is equal to the manipulation of a solar spectroscope. The hardest part is the original adjusting, for which the beginner should insist on careful instructions from the maker. The cost will be about $200 or $250 for a small good one—avoid poor ones. The beautiful and varying solar prominences are better seen through such a spectroscope than through a very large one. And even the solar spectrum considered alone is a thing of beauty.

Any telescope, with clockwork or without, can have a small ocular star spectroscope sufficient to show the different types of stellar spectra magnificently.

As an adjunct a pocket terrestrial spectroscope is a most useful and delightful instrument, as well as cheap and portable (size of a cigar). With it you may examine anything in sight ; lightning, aurora, flames from volcanoes, fireflies, the electric arc light, electric sparks with any electrodes, flame of Bunsen burner and, with some special forms of instrument, meteors, if you are quick enough. Here some valuable work should be done by amateurs as well as anybody else, in the meteoric showers soon due.—Popular Astronomy.

THE LATEST DISCOVERIES AT SILCHESTER.

THE results of the fifth year's work of excavations on the site of the ancient Roman city of Silchester are now on view at the Society of Antiquaries' rooms. As in former years, the society has thrown its rooms open to the public, and free entrance is accorded to all who may care to inspect the objects that have been discovered.

Silchester, as our readers know, is a large area of ground now all but entirely used for agricultural purposes, inclosed by the massive walls of Roman times. The old parish church and a farm house are the only buildings within the walls, and the traveler might very readily follow the public roadway across the area without being aware of the site ever having been once that of a densely populated and important city. The course of the ancient streets has been known for many years, since at harvest time the corn showed a difference of color sufficiently defined to indicate their direction at right angles one to the other.

The site of the Forum has excavated many years ago, and fragments of Corinthian capitals and of their bases of large size were discovered, together with many other objects of unusual interest. In more recent

years the Society of Antiquaries has, with admirable public spirit, devoted itself to a systematic exploration of the site, and year by year a certain portion, bounded by the courses of the ancient streets, has been thoroughly dug over. These insulæ have already yielded important results, for not only have the sites of two quadrangular temples been found close to the parish church, but a great number of private houses of varying capacity have been excavated, and their ground plans recovered. These show many interesting details of planning and construction, of special interest, since in no other site in England has investigation been made with any system on the site of a city, Roman villas in abundance have been investigated, but only here have town houses been laid open for observation. Year by year the results of the excavations have been recorded in these pages, and of special interest was the record of the discovery of what is believed, with every probability, to be the site of a Roman Christian church.

The past year's work has consisted of the excavation of four blocks or insulæ, each bounded and defined, as was the case of the blocks investigated in previous years, by the courses of the ancient streets. These blocks are known as Nos. IX. X. XI. and XII. The whole are close to the city wall, which here forms a well defined angle to the course of the streets, the position being to the northwest of the Forum, the latter defining the center of the city.

Blocks X, XI, and XII form a triangle, having the base formed by the course of a street going east and west, the second side being another street going north and south, while the inclined side is formed by the city wall. Block IX extends to the east of the triangle. The blocks, except XII, are crossed diagonally by the modern public road which goes through the city.

No large or important building has been discovered, with the exception of the foundations of a good house, which has apparently had an open corridor on each side of the dwelling rooms ; only another building, close to it, has been met with which may be considered to have been of domestic character. These two agree fairly well with the houses which have been opened out elsewhere during the excavations of the previous years. All the other buildings now found are of different character, and different also to any that have been discovered in the other cities. They are evidently for manufacturing purposes. They have no good floors, and no signs of fresco painting have been found in any of them. But a good many curious furnaces have been met with of moderate size, built of rough material, and showing signs of continuous use. They are of two forms, circular and oblong, and they occur in positions very different one from the other, some being found within buildings ; many in the open air, clear of all walls. They vary considerably in size, and although none were found in previous years elsewhere, at least twelve have been laid open, and of hearths only, as many as twenty-one, of which twelve are of circular form.

These furnaces, found as they are so close together, show that they were all devoted to the same purpose, and the supposition is supported in the room by the exhibition of a plan of one of the houses at Pompeii, where similar furnaces of later date than the house were found, and which were evidently used for dyeing purposes.

That a dyeing industry was practiced at Silchester hardly admits of a doubt, for apart from the curious furnaces referred to, there have been found several wells, and, in addition, a goodly collection of querns, with which the madder roots for the dyes would have been ground. Elsewhere, notably in Block XII, rooms with underground flues, as if for drying purposes, after the process of dyeing, have been excavated.

All the discoveries that have been made have been laid down to scale on a large plan of the city, which is exhibited, and the results of the last year's work may be briefly stated.

In Block IX four various buildings have been found. They have opened at once from the main street, since their walls come up closely to its line. In like manner, the return streets bounding this block have the buildings close up to them without any intervening forecourts. In the rear, at some distance from the front road, are the two houses already referred to.

Five buildings fill up the frontage of Block X, while a sixth is beyond them, the rest of the site having been vacant.

Block, or "Insula" XI, which comes close up to the city wall, has six buildings of the same character as the others.

Block XII has two small quadrangular buildings, one of which has two diagonal flues crossing each other from the angles, probably used for drying purposes.

In addition to the furnaces and the wells, the area excavated was found to contain a large number of pits, probably old cesspools. These have also been met with pretty generally wherever the ground elsewhere was opened. Many articles of pottery, not, however, of the very best form or manufacture, were found in these, the principal of which are exhibited.

While the buildings here, as well as elsewhere, are mostly set out with careful regard to regularity, and with their lines all at right angles to the streets and to each other, there are some variations. Thus in Block IX one of the four buildings, although it comes quite up to, and its frontage is defined by, the line of the street, is not at right angles to it, which is the more noticeable since the buildings on each side of it are rectangular to the frontage. The dwelling houses in the rear are still more inclined, although at right angles to each other. While the great plan shows all in the city, so far, to be set out so regularly, it is curious to see so complete a change of system in these groups of buildings. Possibly they may be of older date than the setting out of the streets.

Very little of architectural detail has been found ; the principal object is a well moulded capital, with a pin necking, which has been turned in a lathe. A base was also met with, evidently belonging to the same or a similar column. It has two toruses very close to each other, and, like the capital, turned. The material is not unlike a coarse Bath stone, probably oolite, from Gloucestershire. Both had been reused as old material.

A fine slab of even tinted Purbeck marble was also met with, although nothing was found to indicate what position it had occupied. There are clamp holes

at its edges, and since it had been polished only on one face, it would appear that it had been used as a wall lining. But its great thickness almost forbids this supposition. It has been again polished, and the fine grain of the material is shown in consequence to great advantage. The most curious object that has been discovered is a cone of solid stone, about 2 ft. in height, which has had a neatly-worked base, circular, terminating in a square. The form appears Phallic, and it is remarkable for having an Ogam inscription.

Various cases contain the principal small objects found. These consist of bronze personal objects, and articles of toilet, one of which is inlaid with silver. There are also several bone pins, one of jet, a single pretty piece of bronze enameled in a Celtic-like pattern, a few pieces of window glass, and of glass vessels, one of which has part of a pattern produced by grinding, an engraved gem, a gold ring of elaborate pattern, a bronze hinge pierced with an open work pattern of much beauty. Special interest attaches to a hoard of silver coins which were found in a black vase. These extend from Mark Antony to the Emperor Severus. They include a large number of the intervening emperors and empresses, and afford interesting evidence of the length of time in which Roman coins were kept in circulation, for it is evident that the early ones, as well as those of later date, were all current money at the time when they were hidden for security.

A bronze purse, to be worn on the arm, unfortunately empty, is one of the most curious of the small articles.

There are exhibited several pieces of colored wall plaster, decorated with patterns and various tints, but no examples of figured tesselated pavements have been found this year. Indeed, beyond one or two rooms paved with ordinary red tessera, no floors except of very ordinary description, composed of fragments of brick worked up in cement, have been found. But that some pavements of rather better description did exist is shown by the presence of several octagonal paving tiles, exceedingly like those of modern make. But there are no specimens of the small square tiles that were necessary to fill in the intersections.

The large map is a very useful and important feature of the exhibition, for it brings before the spectator the general results of all the previous excavations, and it indicates the large amount of area within the walls that has yet to be laid open. So far about forty only of the 100 acres have been made to reveal the secrets of the long-buried past, and then filled in again for agricultural purposes. It is a matter for regret that funds had not been subscribed so promptly as the importance of the work appears to justify, and we are sorry to see that a balance, although a small one, is due to the treasurer. It is much to be hoped that a work so important as this may be carried on more rapidly during future years, and that the whole area may be investigated within a reasonable period of time.—The Builder, London.

SEDIMENTARY MEASUREMENT OF CRETACEOUS TIME.*

IT is the purpose of this paper to describe certain regular alternations of strata observed in Colorado; to correlate these with an astronomic cycle [of known period, and to deduce from this correlation an estimate in years of a portion of Cretaceous time.

Along the base of the Rocky Mountains, and eastward for many miles, the basin of the Arkansas River is occupied by Cretaceous rocks. At bottom are the Dakota sandstones several hundred feet in thickness; and above these a great body of shales, constituting the Benton, Niobrara and Pierre groups, and having a total thickness of 3,900 feet. In the main these shales are argillaceous ; but at a few horizons they are calcareous, and at one level a sandstone appears, accompanied by a few feet of arenaceous shale. The sandy passage is best developed near the mountains, and disappears altogether toward the east. The calcareous passages are more persistent and have been recognized throughout the district. At least two of them occur many miles farther to the north. As the shales and the associated limestones approach the mountains they do not assume the character of littoral deposits, but remain practically unchanged, and it is thence inferred that the sea in which they were deposited extended to a remote western shore.

The calcareous passages are four in number, and each exhibits a rhythm of sedimentation. The lowest occurs 210 feet above the base of the Benton group, and exhibits an alternation of thin limestone beds with somewhat thicker beds of shale, the shale being more calcareous than the general mass. Each limestone is a few inches in thickness, and the intervening shales are from one to two and one-half feet thick. The average thickness of a pair of beds, including a limestone layer and a shale layer, is eighteen inches, and the number of such repetitions is about fifteen.

Next above are 230 feet of shale, and upon these rest about fifty feet of limestone, constituting the basal member of the Niobrara group. These limestones alternate in an equally regular manner with shales, the layers of limestone being homogeneous and massive, and varying in thickness from one foot to two feet, with three feet as a rare and local maximum. The parting shales range from one to four inches in thickness and are sharply separated from the limestone. The average thickness of the rhythmic couple limestone and shale is, as before, eighteen inches.

The third calcareous series, also of Niobrara age, lies ninety feet above the second, the interval being occupied by shale. Through a thickness of thirty feet calcareous shales alternate with those which are less calcareous, and the amount of calcareous matter increases upward, culminating at the top of the series in two beds of chalky limestone. The average rhythmic interval here is between two and one-half and three feet, and the differences in rock texture are of such character as to give a ribbed appearance to the series where exposed on a cliff face.

The fourth calcareous passage is at the top of the Niobrara group, and is separated from the third by 475 feet of shale. It includes several calcareous layers of which one might be classed as an impure limestone. The rhythmic tendency is clearly manifested, but the number of repetitions is small.

* Read before the Geological Society of America, December 28, 1894.

The Pierre shales, overlying these, have a thickness of about 2,800 feet.

From these data it appears that, in addition to a secular and apparently irregular recurrence of physical conditions leading to the disposition of calcareous matter in this district, there was a relatively rapid and remarkably regular alternation of conditions determining the deposition of alternately more and less calcareous matter. The regularity of this minor alternation suggested the possibility that its cause might be discovered, for of the various causes known or supposed to modify sedimentation, those which recur with uniform rhythm are comparatively rare. So far as we have definite evidence, the purely terrestrial causes, such, for example, as upheaval and subsidence, the shifting of waterways or divides, and the removal of oceanic barriers, are of irregular sequence; but certain astronomic causes are comparatively regular.

There are many astronomic cycles, and their periods vary widely in extent, but there are only a few to which it is reasonable to appeal for explanation of a rhythm in sedimentation. There are, in fact, but three to which geologists have made such appeal, and my own inquiry has discovered no others. I refer to the period of the earth's revolution about the sun, the precessional period, and the variation of the eccentricity of the earth's orbit. Each of these is known or supposed to have an influence on climates, and the nature of sedimentation may in various ways be influenced by climate.

The period of the earth's revolution does not seem applicable to the sedimentary rhythm under consideration, because a year is too short a time for the accumulation of the sediment. Doubtless eighteen inches of sediment are often added in a year to the sea bottom near the mouths of rivers; but when we consider that many centuries are required to degrade the land to an average depth of eighteen inches, that areas of marine sedimentation are in a broad way commensurate with those of terrestrial degradation, and that the Cretaceous sediments under consideration were accumulated scores and perhaps hundreds of miles from the land, we cannot for a moment imagine that they were deposited at so rapid a rate.

The variation of the eccentricity of the earth's orbit has a somewhat regular period of about 91,000 years, but the successive maxima are of so unequal values that they cannot well be correlated with the relatively uniform cycles of deposition.

The precession of the equinoxes seems better qualified to explain the Colorado phenomena. As the earth's axis slowly describes its circle on the celestial sphere the relation of the seasons to perihelion is steadily shifted, so that the winter of the northern hemisphere, for example, occurs during one epoch when the earth is nearest the sun and during another when it is farthest away. The terrestrial consequences of this cycle of change have been discussed by Adhemar, Herschel, Croll, Murphy, Pilar Hill, McGee, Penck, Ramsay, Wallace, Woeikof, Blytt, Ball, Becker and others, and, though there is wide difference of opinion as to the character and amount of the climatic variations which may thus be brought about, these writers are in substantial agreement that the distribution of climates may be materially affected. The precessional period is about 26,000 years, but the position of perihelion also moves—for the most part in a direction opposite to that of the equinoxes—and the resultant of the two motions has an average period of about 21,000 years. It is not absolutely regular, but ranges ordinarily within 10 per cent. of its mean value, and exceptionally to 50 per cent. above and below.

I shall make no attempt to determine what were the climatic oscillations affecting Cretaceous sedimentation in Colorado nor how their influence was exerted. For the purposes of the present discussion it seems sufficient to point out that the local character of sedimentation might be influenced by changes in the local distribution of terrestrial climates:

1. A periodic change in the circulation of the winds might modify the currents of the Cretaceous sea in such way as to bring to this district at one time argillaceous material and at another time calcareous material.

2. A general change of climate producing glaciation about the two poles in alternation, as inferred by Croll and others, might shift the center of gravity of the earth in such way as to make the sea alternately advance against and recede from a coast. Even a small oscillation of this sort might render the principal load transported by streams from a coastal plain alternately chemical and fragmental; and a great oscillation, by causing the coast line to migrate, might periodically revolutionize the distribution of sediments in the sea.

3. If the climate of a broad peneplain were by precession made alternately moist and dry, then during moist epochs it would be densely clothed with vegetation, subterranean waters would be highly charged with organic acids so as to dissolve much lime carbonate, and mechanical degradation would be impeded by the vegetal mat. During dry epochs vegetation would be sparse, water would have little power of solution and relatively rapid mechanical degradation would cause the residual clays to be transported to the ocean.

Adopting 21,000 years as the time unit corresponding to each sedimentary alternation in the calciferous portions of the great shale bed, it remains to estimate the rate of deposition of the more argillaceous portions. As already stated, the sedimentary cycle repeats itself every eighteen inches where the principal deposit is limestone; it also repeats itself every eighteen inches where the limestone makes but one-fourth of the total deposit; and it repeats itself in about 2·7 feet where the calcareous material suffices only to modify an otherwise argillaceous shale. It would appear, then, that the shale was on the whole deposited more rapidly than the limestone, so that in the great bodies of shale something more than 2·7 feet of sedimentation should be correlated with a unit of the time scale. It is moreover true that certain portions of the shale are of different type from those associated with the limestone. This difference does not find definite expression in the chemical composition, but appeals to the eye. All shales near the calcareous passages are pale gray in color, while there are important beds in the upper and lower portions of the Benton series and in the upper part of the Pierre series which are dark gray. These constitute about one-tenth of the entire series. It is

not clear whether we should ascribe a relatively rapid or a relatively slow deposition to the dark shales, but the fact that the shale body is not entirely uniform in character tends to increase the probable error of an estimate of its rate of deposition. It appears to me that an allowance of four feet of local sedimentation for each astronomic cycle should afford a somewhat conservative estimate for the corresponding portion of geologic time. Upon this basis the 3,900 feet of sedimentation required about twenty million years, and this estimate covers the Benton, Niobrara and Pierre epochs. These epochs constitute a part of the Cretaceous period, being preceded in the chronology of the Great Plains province by the Dakota and Comanche epochs and followed by the Fox Hills and Laramie. As the sediments representing those epochs are of different character from the shale to which computation is here applied, the estimate cannot be extended to cover the entire Cretaceous period without materially increasing its probable error.

The reasoning here employed is strictly parallel and partly identical with that of Blytt in his discussion of "The Probable Cause of the Displacement of Beach Lines" (Christiania, 1889). It differs most conspicuously in the interpretation of the influences of dry and moist climates. He correlates fragmental sediments with warmth and moisture, and chemical with coolness and dryness. In discussing the Cenozoic sedimentation of various European countries he finds the alternation of clay and lime carbonate to have an average thickness of 51 inches, nearly three times that observed in the Cretaceous of Colorado.

On the authority of Geelmuyden, Blytt states that the precession period should theoretically have been relatively short in earlier geologic eras, because then the axial rotation was more rapid and the oblateness of the spheroid greater; and to whatever extent this was true in Cretaceous time, the preceding estimate of twenty million years should be diminished.

That the logic of this discussion may be quite clear, some of its leading points are briefly restated. Certain parts of a shale body are found to exhibit a rhythm of sedimentation, the cycles of deposition being repeated in from eighteen to thirty-three inches. After making certain allowances, the average unit of deposition for the whole body of shale is assumed to be four feet. From the regularity of the sedimentary rhythm and the large number of its cycles, it is assumed to have been occasioned by a regular rhythm of conditions. The cycle of deposition is correlated with the precession-perihelion cycle—because this alone, of the various cycles known to the writer, appears competent to explain the phenomena. In discussing its competence, the ability of the precessional cycle to produce climatic oscillations is postulated without argument (because it has already been treated at great length by others), and ways are suggested in which climatic oscillations might result in the observed cycle of sedimentation. Assuming that the general inference is valid, the specific estimate is qualified chiefly by the uncertainty in passing from those portions of the sedimentary column where rhythm finds expression in the alternate abundance and scarcity of lime carbonate to the other and greater portions of the column from which lime carbonate is nearly absent. This uncertainty is believed to be represented by the number 2 as a factor of safety; that is, the true period may be either twice or only one-half the estimated period of twenty million years.

G. K. GILBERT.

THE AGE OF THE EARTH.*

ILL health has hitherto prevented my making the comments which seemed called for by Lord Kelvin's friendly article of March 7, in reply to my communication of January 3. Perhaps I may be allowed not merely to restrict my remarks to this article, but to deal more generally with the subject, in the hope of clearing away the misapprehensions which exist between modern geologists and palæontologists, who are no longer uniformitarians, and physicists who are represented by Lord Kelvin.

The arguments as to the age of life on the earth are based on considerations of (1) geology and palæontology; (2) tidal retardation and shape of the earth; (3) the cooling of the earth from an initially hot condition; (4) the age of the sun.

(1) From geology. Leading geologists declare that the great thickness of sedimentary rocks created since the Lower Cambrian, which are almost the oldest fossiliferous rocks, can only have been produced during many millions of years.

It is difficult to get geologists to give even wide limits for the age of the Lower Cambrian.† Their calculations are based not upon the rate of accumulation of sediment in one of our quiet oceans, but upon the rate of degradation in valleys where the rate is greatest at the present time. They make this declaration, thinking that for the last thirty-three years it has been authoritatively declared by physicists that such an estimate is absurdly great. I have no doubt that they have done their best to keep this estimate as low as possible, for they have a great interest in making geological theory agree with physics. Some physicists tell them that the flaw in the geologists' reasoning consists in their not taking into account the much greater tidal actions of the past. When tides rose and fell many hundreds of feet, and swept over tens or hundreds of miles of foreshore, there must undoubtedly have been a more rapid formation of sedimentary rock than anything of which we now have experience. The geologists' answer is: We acknowledge that all nature's actions were on the whole, possibly, more intense in the past. We know from Prof. Darwin's development of Prof. Purser's theory that the moon was undoubtedly nearer the earth in palæozoic times, and the tide influence was therefore greater. But there seems to

be no method of even approximately calculating how much greater the tidal influence was. While one great astronomical authority speaks of tides of 500 feet deep in palæozoic times, Prof. Darwin himself thinks that two or three times as great as at present may be an excessive estimate. There is a good deal of geological evidence for much smaller seas than at present, and even if tidal influence were greater, the actual tides may have been much smaller than now. Of positive evidence in our favor, we have the fact that numerous examples exist of palæozoic rocks which are identical in almost every physical way with tertiary rocks, and it is difficult to believe that they can have been deposited under very different conditions. Again, nearly all the old sedimentary rocks were laid down near coasts where tidal action would be most violent. Yet even low down in the Cambrian we find the remains of creatures which still have attached to them delicate antennæ. In sandstones we find most delicate ripple marks and the marks of raindrops. But over and above all this, denudation along coast lines can hardly be regarded as of much importance compared with subaerial denudation (Sir A. Geikie, Trans. Geol. Soc. of Glasgow, 1868). Was there more rain? and did it fall more suddenly? Did the wind blow more strongly? Were atmospheric actions more vigorous in the past? There is no great reason for believing that they were. As Prof. G. Darwin observes, fossil trees do not seem to have been built more strongly than modern trees, and this gives some evidence as to the relative violence of aerial forces.

All the geological evidence points to rates of denudation and deposition in the past which may, on the average, have been greater than the average rate at present, but which were not on the average greater than the greatest rates at present.

The palæontologist now comes in. A study of fossils shows that there has been a gradual development, sometimes more quickly perhaps, and sometimes more slowly, but on the whole a continuous development of animal life in the past. We believe from all our study of nature that the development has been continuous. As more and more strata are studied, many of the apparent discontinuities are being converted into continuities. Now even in the lower parts of the Cambrian Brachiopoda are found. Biologists tell us that in all probability these were gradually developed from creatures like worms; their structures are sufficiently complex for us to know that the time taken to develop the Brachiopod from the worm may have been as great as the age of known fossiliferous rocks. There are many rocks, evidently sedimentary, enormously older than the Cambrian, and when laid down there was certainly water on the earth, and hence it was neither too hot nor too cold for animal life. In these lower formations there are conglomerates containing pieces of still older rocks. Although in pre-Cambrian strata traces of animal remains are said to occur, we may say that the palæontological record is almost lost below the Cambrian, most of the earlier rocks having been subjected to great metamorphic action. If we keep to our principle of continuity in nature's actions, we see that the first beginning of life must have taken place at a date many times earlier than the very earliest geological record.

But the most experienced geologists and palæontologists state that they are satisfied with a few hundred million years as the possible age of life or the existence of water on the earth.

(2) The considerations drawn from tidal retardation are as follows:

(α) The shape of the earth now is the same as its shape when it solidified. (β) The shape of a liquid earth tells us its rate revolution on its axis: therefore we know the rate of revolution of the earth on its axis when it solidified. (γ) Assuming that we know, with a fair amount of accuracy, the rate at which the length of the day is altering, we know the date of the earth's solidification, and certainly this is later than 1,000 million years ago.

When I referred to the fallacy in this argument, I did not know that it had already been pointed out by the Rev. M. H. Close and Mr. Clarence King and Prof. George Darwin. It lies in the fact that (α) is certainly wrong. A solid body like the earth will, under the action of great forces, alter its shape in time. Such alteration is continually going on. Again, (γ) is very doubtful.

(3) I now come to the considerations from the cooling of the earth. Lord Kelvin proved that, if the earth was once at a uniform temperature of 7,000° F. or 3,870° C., of material the heat properties of which are the same as the average of three rocks experimented upon at Edinburgh—these remaining constant throughout—and if the rate of increase of temperature downward in the crust is now 1 Centigrade degree for every 90 feet, 100 million years have elapsed since cooling began; but there is a possible maximum of 400 millions.

In the article on this subject, published in Nature, January 3, 1895, I showed that, if we assume greater conductivity in the interior than at the surface, we increase this limit of age. I took a number of examples, which could be worked mathematically. I did not pretend that any one of these represented the actual state of the earth. They merely proved that there were possible internal conditions which might give enormously greater ages than physicists had been inclined to allow. Of my various results, I did not give one as more correct than another, although some may have seemed more probable than others. It was not my object to obtain a correct estimate. Indeed, I tried to show that it was impossible for a physicist to obtain such an estimate, as there were all kinds of possible assumptions which led to many different answers.

The validity of my reasoning in no degree rests upon the accuracy of R. Weber's results as quoted by me. Indeed, I only discovered these results when writing to Professor Tait. In Nature, February 7, p. 341, I have shown the extent to which the possible limit of the earth's age is increased if k and c increase with temperature, and was careful to add: "It must be understood that my conclusions are really independent of whether R. Weber's results are correct or not." It is comparatively unimportant, then, that R. Weber has published another set of results which confirm those which I quoted. The results, published on March 7 for the first time, differ so utterly from the two previous sets, that I venture to

* In this paper free use has been made of many suggestions from Prof. Fitzgerald.

† Their data are of this nature: Of fossiliferous rocks, successively formed the total thickness may be taken as not less than 80,000 feet. Over the areas of the basins drained by many rivers the rate of denudation is known with sufficient accuracy for approximate calculation. Of the basin of the Mississippi a thickness of one foot of rock is removed in 6,000 years; the Ganges, 2,358; the Hoang Ho, 1,464; the Rhone, 1,528; the Danube, 6,846; the Po, 729; the Nith, 4,723 (Sir A. Geikie, Geol. Soc. of Glasgow, 1868). I have heard that Prof. Sollas demands less time than other geologists; but since this paper was written, I have seen (Nature, April 4) that even he does not care to put the age of the Lower Cambrian at much less than 17 million years.

think there may be mistakes in transcribing. However that may be, I am not concerned either to support or refute them.

I mentioned the possible great quasi-conductivity due to the interior of the earth being a honeycombed mass containing liquid, and to the possible greater conduction due to the presence of iron and other metals. Almost anything is possible as to the present internal state of the earth. Dr. Ramsay seems to think that there must be great quantities of sulphides inside, and these would probably be much better conductors than the surface rocks.

Professor Schuster, in discussing the diurnal variation of terrestrial magnetism (Phil. Trans., 1889, p. 467), comes to the conclusion that the electric conductivity of the earth must be considerably greater inside than at the surface.

In all probability there are no great masses of liquid inside the earth at the present time, but it is quite possible that until recent times convection in such masses may have been conveying heat from the very inner earth toward its surface, and the latent heat given out by such masses of liquid as they solidified would be another potent factor. Some distinguished geologists say that the excessive folding which has occurred on the earth's surface cannot be accounted for by the current assumption of physicists, which involves the result that, practically, no cooling has yet taken place below the depth of 120 miles; my assumption is that cooling has taken place to much greater depths.

All these things, like the numbers published by R. Weber, support the argument if they are correct, but they do not in any way destroy it if they are wrong. I was not looking for a probable age of the earth from the point of view of mere physics. I wished to show that the physics' higher limit was greater than a few hundred of millions of years.

Mr. Clarence King's paper appears somewhat inconclusive. He assumes, possibly rightly, that the earth's crust may have the properties of diabase ; experiment has shown what is the rate of increase of the melting temperature with increase of pressure of this rock. Laplace's hypothetical law of increase of density downward in the earth cannot be very wrong, and from this a law of increase of pressure downward may be formulated. From these data Mr. King finds what are the temperatures at various depths, which, if exceeded, would mean liquidity. A liquid layer inside the earth's crust being assumed to be impossible, Mr. King, trying all sorts of Kelvin solutions of a solid earth of uniform conductivity and uniform temperature, initially finds a maximum age of 25 million years, the initial temperature being not greater than 2,000° C.! Furthermore, higher initial temperatures are not possible !

Now it is evident that if we take any probable law of temperature of convective equilibrium at the beginning and assume that there may be greater conductivity inside than on the surface rocks, Mr. King's ingenious test for liquidity will not bar us from almost any great age.

(4) There remain, lastly, considerations drawn from the age of the sun. On the assumption that all the energy possessed by the sun was that due to the mutual gravitation of its parts, and that the sun is now of uniform density, Helmholtz found that the sun may have in the past radiated as much as 22 million times his present annual loss. Langley found that the sun's present rate of radiation was underestimated, and the statement of Professor Newcomb may be taken as that of Helmholtz, corrected. Newcomb says ("Popular Astronomy," p. 533): "If we take the doctrine of the sun's contraction as furnishing the complete explanation of the solar heat during the whole period of the sun's existence, we can readily compute. . . . It is thus found that if the sun had, in the beginning, filled all space, the amount of heat generated by his contraction to his present volume would have been sufficient to last 18 million years at his present rate of radiation."

Lord Kelvin pointed out (pp. 364 to 365, vol. i, "Pop. Lectures") that Helmholtz had assumed a sun of uniform density, whereas the sun's density must increase very much toward his center, and as a result of calculation on the assumption that only half of the original energy was available (p. 374), that the radiation was greater in the past, and that the original collisions occurred practically simultaneously, he says : "We may therefore accept as the lowest estimate for the sun's initial heat 10,000,000 times a year's supply at present rate, but 50,000,000 or 100,000,000 as possible, in consequence of the sun's greater density in his central parts." And again (p. 375) : "It seems therefore, on the whole, most probable that the sun has not illuminated the earth for 100,000,000 years, and almost certain that he has not done so for 500,000,000 years. This last number, then, is Lord Kelvin's higher limit. After six years, in 1868, Lord Kelvin returned to the question, and he says (p. 53, vol. ii, "Pop. Lectures and Addresses") : "The estimates here are necessarily very vague, but yet vague as they are, I do not know that it is possible, upon any reasonable estimate, founded on known properties of matter, to say that we can believe the sun has really illuminated the earth for five hundred million years."

In his R. I. address of 1887, Lord Kelvin gave no higher limit. I think that, on his assigned assumptions in giving these large numbers, he has been very generous ; for, taking Mr. Homer Lane's determination of the internal density of the sun, I find that the Helmholtz total energy need only be multiplied by about 2½. If, however, instead of taking, as Mr. H. Lane did, 1·4 as the ratio of specific heat, we take a less number, and there is no reason why we should not, we find much greater densities toward the center, and a much greater total energy and age. Still, I think that it is only when we escape from the above assumptions that we can see our way to increase the higher limits which have been quoted.

To justify the Helmholtz hypothesis of mere mutual attraction, initially, between the portions of matter which form the sun, Lord Kelvin ("Pop. Lect.," vol. i, pp. 411-3) dwells upon the great improbability that any parts of the sun possessed much initial velocity. He shows that if two bodies, A and B, came together to form the sun, when the bodies were still far apart before collision the motion of the center of B relatively

pass nearly through the center of A (as the sun has a comparatively small moment of momentum), and this was very improbable if the bodies had initial velocities. But this argument is only satisfactory when the bodies coming together are two in number. For example, let us imagine in early times a sun of half the mass of the present one, but of many times its diameter. It is possible that its radiant energy was supplied by meteors. If the meteor feeding was in excess, the sun became larger in volume. If there was too little meteor feeding, the sun became smaller. Even if there was a very excessive supply for a short time, say by the incoming of a huge meteor, we need not assume excessive radiation in consequence. Such meteors may have come from stellar space with great initial velocities, and may have possessed before collision many times the kinetic energy which a mere solar system meteor of the same mass would possess.[*] If there were many such meteors, their paths might be enormously out of line with one another and with the center of the sun, and yet we need not imagine them to alter much the moment of momentum of the sun about its axis. If we look for the probable age of the sun as deduced from mere physics, we ought to take Helmholtz's condition of mere mutual attraction, the Helmholtz calculation being corrected of course for greater internal density : but if we look for a higher limit to the age of the sun, it is difficult to see why we may not multiply Lord Kelvin's total energy and age of 500 million years.

Again, the ages determined by Von Helmholtz, Prof. Newcomb, and Lord Kelvin are given on the uniformitarian assumption that the sun has been radiating energy always at his present rate. If we may imagine that for long periods the sun radiated at a smaller rate, whether because his mass was smaller or because of his atmosphere, we again have an increase to the calculated age. Prof. Newcomb seems to have noticed this, and to meet the objection (p. 525, "Popular Astronomy") he says, that "a diminution of the solar heat by less than one-fourth of its amount would probably make our earth so cold that all the water on its surface would freeze, while an increase by much more than one-half would probably boil the water all away." On account of this exigency, indeed, he reduces his previous estimate in the ratio of nine to five. This statement ought to have the careful consideration of men who know more about astronomical physics than I do. It means that if the earth were now 15¼ per cent. further away from the sun, there would be no water and no life, only ice ; and if we were 18·4 per cent. nearer the sun, there would be again no water and no life, only steam. It becomes an important question, Is there no life, is there no water, on the planet Venus, which has twice our solar radiation? Is all its water in its atmosphere as steam? Again, Mars has only 40 per cent. of our solar radiation; is there no life, no water, only ice, upon Mars? I have no right to speak on such a subject, but I understood that the atmosphere of Venus was much like that of our own planet, and that the water of Mars is not all ice, for his polar snow caps are seen to melt in summer. True, they may be solid carbonic acid, but I have recently read that the green color of vegetation had been observed to appear and disappear regularly on the planet. If there is little water on the surface of Mars, I should imagine that this is rather due to its having soaked into the crust, which is probably colder under ground than ours. Prof. Newcomb has evidently not thought of Mars in this connection, for elsewhere he says : "If there are any astronomers on Mars . . ." On this question I venture to quote Lord Kelvin, who said, in 1887 ("Pop. Lect." vol. i, p. 376), that "the intensity of the solar radiation to the earth is 6¼ per cent. greater in January than in July ; and neither at the equator nor in the northern or southern hemispheres has this difference been discovered by experience or general observation of any kind." It is difficult to imagine that if the effect of 6¼ per cent. cannot be detected, 25 per cent. should convert all the water to ice and destroy all life.

Even if a small diminution of the solar radiation produced a very cold climate on our present earth, we must remember that the earth's atmosphere may have been very different in the past ; the earth may have been very greatly blanketed, and the surface may have been actually warmer, although there was much less solar radiation. That the atmosphere is far more important in this connection than the amount of solar radiation, is evident if we consider Langley's determination that in the tropics, if there were no atmosphere, the temperature of the surface of the earth would be −200° C. Any addition to the quantity of air in our present atmosphere means an increase of the temperature of the rocky surface. But in the past, not only may there have been more atmosphere, but there may have been a very different kind of atmosphere. Again, we must consider a possible great amelioration of climate due to the earth's internal heat. It could not occur by mere conduction, but it is quite possible that for many millions of years there was great blanketing by clouds of watery vapor, and that underneath these blankets half the surface of the globe may have been a lake, or a number of lakes of melted lava, which may have carried large amounts of heat convectively from considerable depths, this heat again being carried about convectively by the earth's atmosphere, keeping the solid parts of the earth's surface in a fit state for the existence of low forms of animal life. It is possible that at the present time the surface of Jupiter, which receives a very small intensity of solar radiation, may have solid parts surrounding watery lakes and oceans capable of supporting life because of the existence of many lakes of melted lava.

To sum up, we can find no published record of any lower maximum age of life on the earth as calculated by physicists (I leave out the estimates based upon the assumption of uniform density in the sun, and also that of Mr. Clarence King) than 400 million years. From the three physical arguments, Lord Kelvin's higher limits are 1,000, 400, and 500 million years. I have shown that we have reasons for believing that the age, from all three, may be very considerably underestimated. It is to be observed that if we exclude everything but the arguments from mere physics, the probable age of life on the earth is much less than any of the above estimates : but if the paleontologists

*The velocities of stars are probably much less than the possible veloci-

have good reasons for demanding much greater time, I see nothing from the physicist's point of view which denies them four times the greatest of these estimates.

JOHN PERRY.

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